Richmond National Battlefield Park

Virginia

Water Resources Management Plan

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EXECUTIVE SUMMARY

Richmond National Battlefield Park (Richmond NBP) consists of 1,366 acres in 11 geographically separate units that are located primarily east, northeast, and southeast of the city of Richmond, Virginia. This Water Resources Management Plan addresses nine of the units: Beaver Dam Creek, Chickahominy Bluff, Cold Harbor (including the Garthright House), Drewry's Bluff, Fort Harrison, Gaines' Mill, and Glendale and Malvern Hill. The units are in the Atlantic Coastal Plain Physiographic Province between the James and York rivers. The small streams that drain each of the units are tributaries of either the Chickahominy River or James River and ultimately contribute to the Chesapeake Bay.

This Water Resources Management Plan was developed cooperatively by the National Park Service's Water Resources Division, Richmond National Battlefield Park, and the U.S. Geological Survey to assist park management in the understanding and management of these resources. It provides an overview of existing resource conditions, identifies water-related management issues, and presents alternatives addressing water resources issues and management within the park boundaries.

Little specific information is known about water quantity, water quality, wetland and riparian areas, and the water-dependent flora and fauna in the park units. Although it appears that the quality of water is good in most of the park units, encroaching suburban development threatens the future integrity of the water and aquatic biota on parklands. The U.S. Geological Survey completed a Level I Water-Quality Inventory and Monitoring (WAQIM) assessment in 2002; results are included in this report.

Water-resources related issues discussed in this report include the following:

- Adequacy of current water-quality information to assess potential water-quality degradation from nonpoint-source pollution related to changing land use. There are no baseline data to document the current water quality in the park units, other than the recently completed WAQIM. Projection of population growth in the lands surrounding the park units indicates that development likely will occur, along with associated nonpoint-source pollution, which will directly affect the quality of water in the park units.
- Wetland and riparian resource management. There have been no inventories of riparian flora and fauna in the park units. Assessment of the existing riparian flora and fauna is important for identifying threatened and endangered species and for establishing a baseline of information against which future changes in quality and diversity can be made.
- Adequacy of inventory of water-dependent flora and fauna. Likewise, there have been no inventories of water-dependent flora and fauna in the park units. This lack of documentation makes it impossible to detect changes in, or deterioration of, the resources, determine the presence/absence of state and federally listed species, and detect the presence and potential impacts of invasive exotic species.
- Invasive exotic species.

- Adopting a proactive culture to protect park lands.

Three proposed project statements were developed that address the first three water-resources issues. The first project statement describes biological monitoring to establish a baseline of water-quality ratings in streams in the park units. The second project statement describes procedures to assess the proper functioning condition of riparian areas and associated flora and fauna in the park units. And the third project statement describes procedures to conduct a comprehensive inventory of water-dependent flora and fauna to determine the status of existing species, the presence of additional rare, threatened, or endangered species, and the presence of invasive exotic species.

THE WATER RESOURCES MANAGEMENT PLAN AND NEPA

The National Environmental Policy Act (NEPA) mandates that federal agencies prepare a study of the impacts of major federal actions that have a significant effect on the human environment and alternatives to those actions. The adoption of any formal plans may be considered a major federal action requiring NEPA analysis if such plans contain decisions that affect resource use, examine options, commit resources or preclude future choices. Because it lacks these elements, this Water Resources Management Plan has no measurable impacts on the human environment and is categorically excluded from further NEPA analysis.

According to Director's Order (DO) #12 Handbook (section 3.4), Water Resources Management Plans normally will be covered by one or more of the following Categorical Exclusions from NEPA:

3.4.B (1) Changes or amendments to an approved plan when such changes have no potential for environmental impact.
3.4.B (4) Plans, including priorities, justifications, and strategies, for non-manipulative research, monitoring, inventorying, and information gathering.
3.4.B (7) Adoption or approval of academic or research surveys, studies, reports and similar documents that do not contain and will not result in NPS recommendations.
3.4.E (2) Restoration of non-controversial native species into suitable habitats within their historic range.
3.4.E (4) Removal of non-historic materials and structures in order to restore natural conditions when the removal has no potential for environmental impacts, including impacts to cultural landscapes or archeological resources.
3.4.E (6) Non-destructive data collection, inventory, study, research, and monitoring activities.
3.4.E (7) Designation of environmental study areas and research natural areas, including those closed temporarily or permanently to the public, unless the potential for environmental (including socioeconomic) impact exists.

These Categorical Exclusions require that formal records be completed (Section 3.2, D0-12 Handbook) and placed in park files. It is the responsibility of Richmond NBP to complete the documentation for the applicable Categorical Exclusion(s) when the Water Resources Management Plan is approved and published.

INTRODUCTION

Whether supporting natural systems or providing for visitor use, water is a significant resource in units of the national park system. Consistent with its fundamental purpose, the National Park Service seeks to protect surface and ground waters as integral components of a park's aquatic and terrestrial ecosystems by carefully managing the consumptive use of water and striving to maintain the natural quality of surface and ground waters in accordance with all applicable federal, state, and local laws and regulations. In particular, aquatic ecosystem health is dependent upon the maintenance of adequate water quality. All sources of water, even seeps, springs, and ephemeral streams, are potentially critical to maintaining the riparian and aquatic habitat that supports the local flora and fauna and therefore are essential to maintaining the park's biodiversity.

Competing pressures on Richmond National Battlefield Park (NBP) lands, such as expected changes in land use, existing and proposed development within and outside of park boundaries, nonpoint-source pollutants, proximity to point-source pollutants, and natural processes are potential threats to the integrity of water quality and quantity in the park. Because of these pressures, and potential degradation to the natural resources in the park, this Water Resources Management Plan was written for Richmond NBP. The primary purpose of this Water Resources Management Plan is to assist park managers with water-related decisions. In this regard, the plan provides a detailed overview of existing water resources information; identifies and discusses a number of water resource-related issues and management concerns; and presents courses of actions for addressing high-priority water resource-related issues at Richmond NBP. Project statements regarding critical water resource issues are included and can be incorporated into the National Park Service's PMIS system and the park's Resource Management Plan (National Park Service 1994) for future funding consideration.

PARK SETTING

Richmond NBP is 110 miles south of Washington, D.C., in east-central Virginia, and comprises 1,366 acres within the general vicinity of the city of Richmond (Figure 1). The park contains 11 geographically separate units, located primarily east, northeast, and southeast of the city of Richmond. Ten of the units are associated with McClellan's 1862 Peninsula Campaign or Grant's 1864 Overland Campaign during the Civil War. The 11th unit, located within the city limits, was the site of the Confederacy's Chimborazo Hospital and is now the main park Visitor's Center. Richmond NBP was established by federal legislation in 1936 to "protect the Civil War battlefield resources associated with the struggle for the capital of the Confederacy and to interpret these resources so as to foster an understanding of their larger significance" (National Park Service 1996).

The units comprising Richmond NBP are situated on the peninsula formed by the James and York rivers, east of the transition zone (the Fall Line) that separates the Piedmont and Atlantic Coastal Plain Physiographic provinces. Location details of the nine units discussed in this report—Beaver Dam Creek, Chickahominy Bluff, Cold Harbor (including the Garthright House), Drewry's Bluff, Fort Harrison, Gaines' Mill, Malvern Hill, and Glendale—are shown in Table 1. Although Malvern Hill and Glendale considered separate units, because of their proximity they are combined and discussed together in this report. Correspondingly, the Cold Harbor unit and the Garthright House are combined and discussed as one unit. The Chimborazo and Parker's Battery units (15.6 acres combined) were determined to contain no significant water resources and are not discussed in this report.

Table 1. Location and area of park units.

Unit	Area (acres)	County	USGS 1:24,000-scale Virginia topographic quadrangle
Beaver Dam Creek	16.2	Hanover	Seven Pines
Chickahominy Bluff	37.0	Henrico	Richmond
Cold Harbor/ Garthright House	151.1	Hanover	Seven Pines
Drewry's Bluff	39.5	Chesterfield	Drewry's Bluff
Fort Harrison	312.8	Henrico	Dutch Gap
Gaines' Mill	59.7	Hanover	Seven Pines
Malvern Hill/Glendale	733.9	Henrico	Dutch Gap and Roxbury

HYDROLOGIC UNIT CODES

The following text is quoted from < http://www.ftw.nrcs.usda.gov/huc_data.html > of the National Resources Conservation Service:

"Hydrologic unit boundaries define the areal extent of surface water drainage to a point. The goal of this initiative is to provide a hydrologically correct, seamless and consistent national Geographic Information System (GIS) database at a scale of 1:24,000, that has been extensively reviewed and matches the USGS topographical 7.5 minute quads. The new levels are called watershed (5th level, 10-digit) and subwatershed (6th level, 12-digit). The watershed level is typically 40,000 to 250,000 acres and subwatershed level is typically 10,000 to 40,000 acres with some as small as 3,000 acres. An estimated 22,000 watersheds and 160,000 subwatersheds will be mapped to the 5th and 6th level. The GIS coverages will be available by the Internet to any person, including federal, state, local government agencies, researchers, private companies, utilities, environmental groups, and concerned citizens. The database will assist in planning and describing water use and related land use activities.

During the 1970's the USGS developed a hierarchical hydrologic unit code (HUC) for the United States. This system divides the country into 21 Regions, 222 Subregions, 352 Accounting Units, and 2,149 Cataloging units based on surface hydrologic features. The smallest USGS unit (8-digit HUC) is approximately 448,000 acres. During the late 1970's the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation

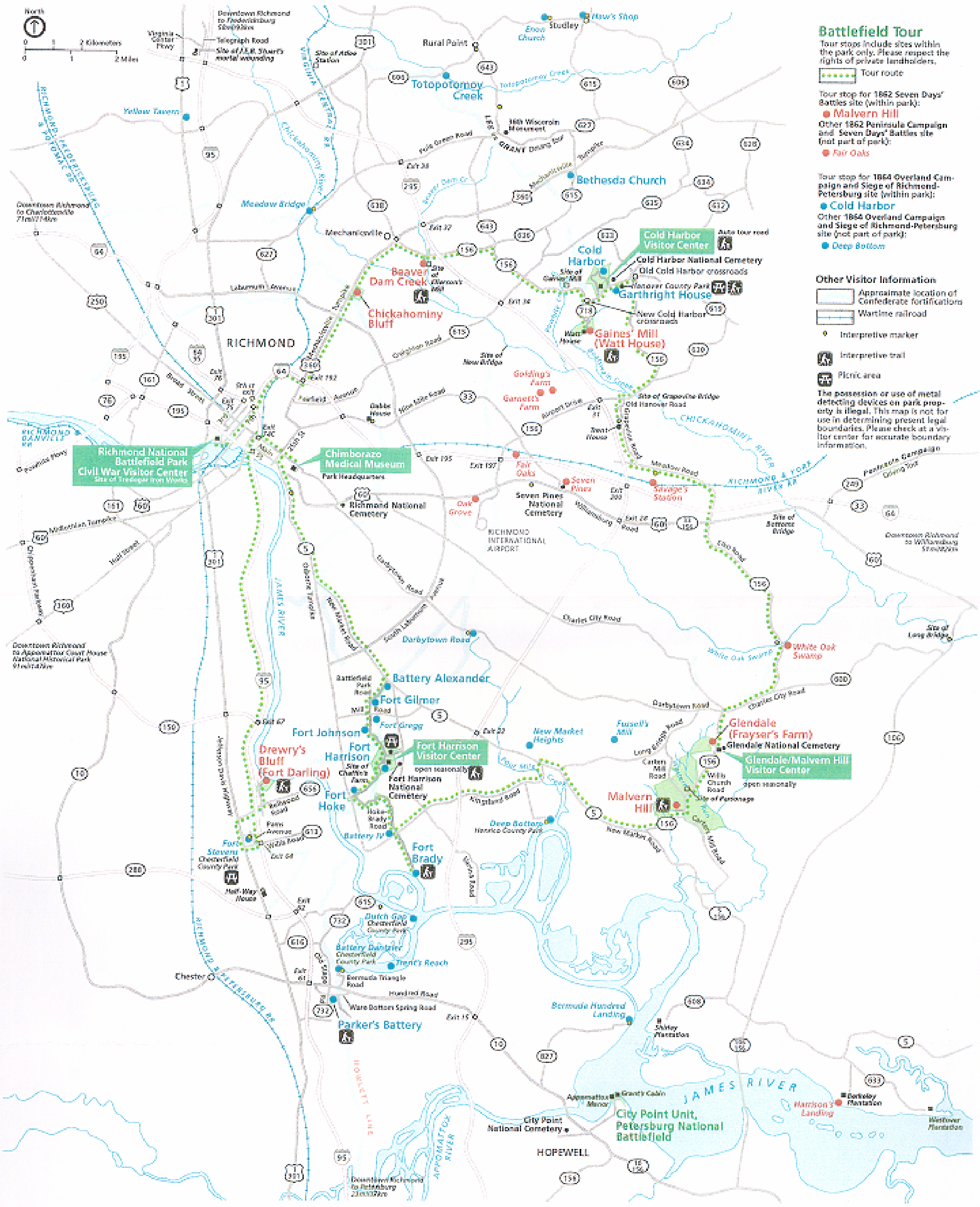

Figure1. Map showing location of Richmond National Battlefield Park units.

Service, initiated a national program to further subdivide HUC's into smaller watersheds for water resources planning. A 3-digit extension was added to the 8-digit I.D. By the early 1980's this 11-digit HU mapping was completed for most of the U.S. During the 1980's several NRCS state offices starting mapping watersheds into subwatersheds by adding 2 or 3-digits to the 11-digit HUC. By the late 1980's and early 1990's the advent of GIS made the mapping of digital HU boundaries feasible. At this time, the NRCS decided to delineate and map the entire U.S. to the 11 and 14-digit level.

The mapping would be done by the use of GIS incorporating DEM's, DRG's, and a variety of geospatial data and techniques. A national standard (NI-170-304-superceeded by National Interagency Guidelines) established procedures and specifications for delineating and mapping hydrologic units (HU's). These guidelines help ensure accurate and consistent HU boundaries nationwide and the digital database is usable with other natural resource digital data layers in a GIS. The national standard was issued in 1992; since then, it has continued to be updated. The 1995 version is available as NI 170-304 along with a summary of updates made since June 1995. This effort to delineate and digitize the HU's is coordinated by each NRCS state office in coordination with other federal, state, and local agencies, and others interested in the effort. NCGC is providing coordination, verification, and certification (Power Point Slides) of state datasets, as well as integrating the state coverages into one national HU dataset. A list of state contacts for the effort is available.

Over the last several years many federal and state agencies have realized current 8-digit hydrologic unit (HU) maps are unsatisfactory for many purposes, because of inadequate bases or scales. Because of this, the NRCS has continued to work with other federal and state agencies and with the Subcommittee on Spatial Water Data Federal Geographic Data Committee (FGDC) to establish a Federal interagency standard covering mapping and delineation of hydrologic units that would be suitable for all agencies. In cooperation with the FGDC and the Advisory Committee on Water Information (ACWI), a new interagency guideline has been written. During December of 2000, this document was presented to the FGDC for their review. This document has superseded NI 170-304 as the official standard for delineation of 5th and 6th level hydrologic units. Over the last couple of years, a series of workshops have been held to promote this interagency effort and to resolve subwatershed delineation issues."

According to < http://www.ftw.nrcs.usda.gov/HUC/hucstatusstate.jpg >, the watershed boundary data set for Virginia is 25-75% complete, as of August 29, 2002. Because the data set is incomplete, 12-digit HUC's are not available for inclusion in this report. Once the data set has been completed, the park is urged to obtain the 12-digit HUC's for all streams within park boundaries. Contacts in Virginia on this initiative are Karl Huber, 804-371-7484 (khuber@dcr.state.va.us) and Fred Garst, 540-434-1404 (fred.garst@ vaharrison.fsc.usda.gov).

WATER RESOURCES MANAGEMENT PLAN

A Water Resources Management Plan is a tool to support the decision-making process of the National Park Service related to the protection, conservation, use, and management of a park's water resources. The Water Resources Management Plan is a component of a park's overall resource management program and serves as a supplemental implementation plan appended to the park's Resource Management Plan (RMP). By compiling pertinent information about the park's water resources and water-related environments, and by identifying water-resources issues facing the park, the Water Resources Management Plan assists management in developing and evaluating alternative actions for addressing these issues and selecting a preferred course of action.

Actions recommended in the Water Resources Management Plan are incorporated into the RMP through the development of Project Statements. Project Statements are standard National Park Service programming documents that describe a problem or issue, discuss actions to deal with it, and identify additional staff and/or funds needed to carry out the proposed actions. Project Statements are planning tools used to identify problems and needed actions, and are used to compete with other projects and park units for funds and staff.

Project Statements address water issues within the context of a suite of management objectives that are either formulated during the water-resources management planning process or during some previous planning process, such as the RMP or General Management Plan (GMP). Specific management objectives for Richmond NBP identified in the RMP (National Park Service 1994) are as follows:

1) To identify, evaluate, protect, restore and preserve park cultural resources important to the understanding of the military actions during the 1862 Peninsula Campaign and the 1864 and 1865 battle actions that resulted in the final struggle for Richmond;

2) To provide a historical context that will foster public understanding of battlefield actions, military strategies, and the role of the City of Richmond during the Civil War;

3) To promote the identification and conservation of important Richmond area Civil War battlefields and associated resources not currently in park ownership through cooperative Federal, State, County and private actions;

4) To make all of the units easily available and accessible to the visitor; and

5) To interpret each site in its overall historical context.

The common thread among Project Statements, issues, and management objectives is the cornerstone of issue-driven planning. Three Project Statements designed to address water-resource issues specific to Richmond NBP are included in this report.

Data used to develop this Water Resources Management Plan were compiled from the existing body of data and literature available from government agencies (including Richmond NBP), local universities, and other entities with knowledge of water-related conditions in the vicinity of the park.

HISTORICAL CONTEXT OF WATER-RELATED RESOURCES

Waterways constitute significant features in the Coastal Plain of eastern Virginia. Major hydrologic features such as the Rappahannock, Pamunkey, North Anna, and Chickahominy rivers served as natural lines for the defense of Richmond throughout the Civil War. Federal commanders McClellan, Meade, and Grant had to take these watery obstacles into account when planning any approach to Richmond from the north or northeast. On the other hand, rivers such as the Rappahannock, Pamunkey, York and James also provided the vital supply routes for the Federal army during both the Peninsula (1862) and Overland (1864) campaigns (Inners *et al.* 1995). While the water-related terrain features at the battles of Beaver Dam Creek (1862), Cold Harbor (1864), Gaines' Mill (1862), Glendale (1862), and Malvern Hill (1862) were more subtle, they may be considered as contributory factors in both tactics and troop movements that led to success or failure during those costly battles.

THE CULTURAL LANDSCAPE AND NATURAL RESOURCES

The park's GMP proposed several studies to be done, including national register nominations, archeological resource studies, cultural landscape assessments, and historic resource studies. In particular, a cultural landscape assessment has been completed for one park unit and another is in progress. Ultimately, these assessments propose how the park should treat the cultural landscape of a particular unit.

The treatment of a cultural landscape should preserve significant physical attributes, biotic systems, and uses when those uses contribute to historic significance. Treatment decisions should be based on a cultural landscape's historic significance over time, existing conditions, and use. Treatment decisions should consider both the natural and built characteristics and features of a landscape, the dynamics inherent in natural processes and continued use, and the concerns of traditionally associated peoples.

The treatment implemented should be based on sound preservation practices to enable long-term preservation of a resource's historic features, qualities, and materials. There are three types of treatment for extant cultural landscapes: preservation, rehabilitation, and restoration.

A treatment is a physical intervention carried out to achieve a historic preservation goal. There are many practical and philosophical variables that influence the selection of a treatment for a landscape. These include, but are not limited to, the extent of historic documentation, existing physical conditions, historic value, proposed use, long and short term objectives, operational and code requirements (e.g. accessibility, fire, security) and anticipated capital improvement, staffing, and maintenance costs. The impact of the treatment on any significant archeological and natural resources should also be considered in this decision making process. Therefore, it is necessary to consider a broad array of dynamic and interrelated variables in selecting a treatment for a cultural landscape preservation project.

Cultural landscapes commonly derive their character from a human response to natural features and systems. The significance of these natural resources may be based on their cultural associations and from their inherent ecological values. Natural resources form natural systems that are interdependent on one another and which may extend well beyond the boundary of the historic property. For example, these systems can include geology, hydrology, plant and animal habitats, and climate. Some of these natural resources are particularly susceptible to disturbances caused by changes in landscape management. Many natural resources such as wetlands, water quality or rare species also fall under local, state, and federal regulations -- after all, natural systems are an integral part of the cultural landscape and should be considered when selecting an appropriate treatment.

Any cultural landscape preservation planning effort should include experts in natural resource areas to address specific issues or resources found within a cultural landscape. These experts would be important in the early planning stages so that any loss of a landscape's character-defining features is avoided. Additionally, they can assist in securing any required natural resource-based permits and licenses and coordinating with public agencies responsible for overseeing specific environmental concerns.

PLANNING CONSIDERATIONS

Numerous federal and state laws, policies, and executive orders mandate specific regulatory considerations with regard to protection and management of water-related resources in and adjacent to Richmond NBP. Additionally, policies and guidelines of the National Park Service broadly require management of natural resources of the national park system to maintain, rehabilitate and perpetuate the inherent integrity of aquatic resources.

The lands and waters of Richmond NBP are subject to myriad regulatory, planning, and management authorities, at least in part because of the geographic separation of the units. Many federal, state and local agencies have an interest, mandated or otherwise, in the water resources within the park. Protection of water resources requires an understanding of the various policy, regulatory, and management designations to facilitate coordination of all agency efforts and other landowners within the watershed. The following section of this report describes federal, state, and local legislation, regulatory designations and management oversight authorities that apply to Richmond NBP.

FEDERAL LEGISLATION, POLICIES, AND EXECUTIVE ORDERS

Section 10 of the Rivers and Harbors Appropriations Act of 1899, as amended (33 USC 403)

This was the first general legislation giving the U.S. Army Corps of Engineers jurisdiction and authority over the protection of navigable waters. Navigable waters of the United States are those waters that are subject to the ebb and flow of the tide and/or are presently used, have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. U.S. Army Corps of Engineers permits are required under Section 10 for structures and/or work in or affecting navigable waters of the United States.

The U.S. Army Corps of Engineers began regulation of wetlands under this act, and then received a much broader grant of jurisdictional authority under the Clean Water Act. Because of the broader geographic reach of "waters of the United States" jurisdiction under the Clean Water Act, Rivers and Harbors Act jurisdiction usually will not be of significance to wetlands regulation in current cases. There are, however, several situations in which Rivers and Harbors Act jurisdiction alone will be available: when an exemption from Section 404 coverage applies, and when activities, as opposed to waters, are covered by the Rivers and Harbors Act and not the Clean Water Act. For instance, the mooring of houseboats in a bay may require a permit under the Rivers and Harbors Act, but would not be under the jurisdiction of the Clean Water Act.

National Park Service Organic Act of 1916

Through this act, Congress established the National Park Service and mandated that it "shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of future generations." Congress, recognizing that the enjoyment by future generations of the national parks can be ensured only if the superb quality of park resources and values is left unimpaired, has provided that when there is a conflict between conserving resources and values and providing for enjoyment of them, conservation is to be predominant. This is how courts have consistently interpreted the Organic Act.

National Environmental Policy Act of 1969 (NEPA)

Congress passed the National Environmental Policy Act (NEPA) in 1969. Environmental compliance in the National Park Service encompasses the mandates of NEPA and all other federal environmental laws that require evaluation, documentation and disclosure, and public involvement, including the Endangered Species Act, Clean Water Act, Executive Orders on Floodplains and Wetlands, and others.

NEPA established a general federal policy for the responsibility of each generation as trustee of the environment for the succeeding generations. Specifically, NEPA requires that an environmental impact statement (EIS) be prepared as part of the review and approval process by federal agencies of major actions that significantly affect the quality of human life. The primary purposes of an EIS are to ensure that there is an evaluation of the impacts of proposed projects and to facilitate public review. An environmental assessment may be prepared prior to initiating an EIS in order to determine if the preparation of an EIS is required. Specific agency guidance is available in National Park Service Director's Order 12: Conservation Planning and Environmental Impact Analysis (National Park Service, in preparation).

Regulations implementing NEPA require the cooperation of federal agencies in the NEPA process. The regulations also encourage the reduction of duplication through cooperation of federal agencies with state and local agencies, including early efforts of joint planning, joint hearings and joint environmental assessments.

All natural resource management and scientific activities are subject to environmental analysis under NEPA through the development of environmental assessments and environmental impact statements. Parks are encouraged to participate as cooperating agencies in the environmental compliance process to the fullest extent possible when National Park Service resources may be affected, and as set forth in Council on Environmental Quality (CEQ) regulations. Participation by the National Park Service in the environmental compliance processes of other agencies and jurisdictions is an important management tool. It can provide the National Park Service with information that will allow the Service to respond to possible external threats to a park well before they occur.

Section 102 of NEPA sets forth a procedural means for compliance. The CEQ regulations further define the requirements for compliance with NEPA.

An environmental assessment is not included as part of this Water Resources Management Plan because this plan provides a general direction for the water resources program for the park. Where appropriate, compliance with NEPA will be undertaken for specific actions resulting from this plan, when it becomes apparent that individual actions, or groups of actions, will be implemented.

General Authorities Act of 1970

In recognition of the growing diversity of units and resources in the National Park System, Congress reinforced the primary mandate in 1970, through the General Authorities Act. This legislation states that all park lands are united by a common preservation purpose, regardless of title or designation. Hence, all water resources in the National Park System, including Richmond NBP, whose purpose is cultural, are protected equally, and it is the fundamental duty of the National Park Service to protect those resources unless Congress specifically provides for exceptions.

The dual, and sometimes conflicting, mandates to preserve and protect resources while providing for their enjoyment by the public often complicates park management. Achieving a balance is at the heart of most decisions affecting the management of the park.

Clean Air Act of 1970, as amended in 1990

The Clean Air Act regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The 1990 amendments to this act were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground-level ozone, stratospheric ozone depletion and air toxics. The amendments identify a list of 189 hazardous air pollutants. The U.S. EPA must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations. That list includes PCBs; dioxins and furans; chlordane, mercury compounds; lead compounds; cadmium compounds; toxaphene; and trichlorobenzene, to name a few.

The Clean Air Act directs the U.S. EPA to monitor, assess, and report on the deposition of toxic air pollutants to the "Great Waters," which include the Chesapeake Bay. Activities include establishing a deposition-monitoring network, investigating sources of pollution, improving monitoring methods, evaluating adverse effects, and sampling for the pollutants in aquatic plants and wildlife.

Federal Water Pollution Control Act (Clean Water Act) of 1972

The Federal Water Pollution Control Act, more commonly know as the Clean Water Act, was first promulgated in 1972 and amended in 1977, 1987, and 1990. This law is designed to restore and maintain the chemical, physical and biological integrity of the nation's waters, including the waters of the national park system. To achieve this, the act called for a major grant program to assist in the construction of municipal sewage treatment facilities, and a program of effluent limitations designed to limit the amount of pollutants that could be discharged. Effluent limitations are the basis for permits issued for all point source discharges, known as the National Pollutant Discharge Elimination System (NPDES).

As part of the act, Congress recognized the primary role of the states in managing and regulating the nation's water quality. Section 313 requires that all federal agencies comply with the requirements of state law for water-quality management, regardless of other jurisdictional status or landownership. States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water-quality standards. Water-quality standards consist of the designated use or uses made of a water body or segment, water-quality criteria necessary to protect those uses and an anti-degradation provision that may protect the existing water quality. Best management practices are defined by the U.S. Environmental Protection Agency (EPA) as methods, measures or practices selected by an agency to meet its nonpoint control needs. These practices include but are not limited to structural and non-structural controls and operations and maintenance procedures. They can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving waters.

A state's antidegradation policy is a three-tiered approach to maintaining and protecting various levels of water quality. Minimally, the existing uses of a water segment and the quality level necessary to protect the uses must be maintained. The second level provides protection of existing water quality in segments where quality exceeds the fishable/swimmable goals of the Clean Water Act. The third level provides protection of the state's highest quality waters where ordinary use classifications may not suffice; these are classified as Outstanding National Resources Waters (ONRW).

Section 303 of the act requires the promulgation of water-quality standards by the states. Additionally, each state is required to review its water-quality standards at least once every three years. This section also requires the listing of those waters where effluent limitations are not stringent enough to implement any water-quality standard [so called 303(d) list]. Each state must establish, for each of the waters listed, total maximum daily loads for applicable pollutants. The regulations also provide for the listing of waters that do not meet standards because of nonpoint source pollution.

Section 401 requires that any applicant for a federal license or permit to conduct an activity which will result in a discharge into waters of the U.S., shall provide the federal agency, from which a permit is sought, a certificate from the state water pollution control agency stating that any such discharge will comply with applicable water quality standards.

Section 402 of the Clean Water Act requires that a National Pollutant Discharge Elimination System (NPDES) permit be obtained for the discharge of pollutants from any point source into the waters of the United States. "Point source", "waters of the United States" and "pollutants" are all broadly defined under the act, but generally all discharges and storm-water runoff from municipalities, major industrial and transportation activities, and certain construction activities must be covered under a NPDES program permit. The U.S. EPA usually delegates NPDES permitting authority to a state. The state, through the permit process, establishes the effluent limitations and monitoring requirements for the types and quantities of pollutants that may be discharged into its waters. Under the antidegradation policy, the state must also insure that the approval of any NPDES permit will not eliminate or otherwise impair any designated uses of the receiving waters.

Section 404 of the Clean Water Act requires that a permit be issued for discharge of dredged or fill materials in waters of the United States including wetlands. The U.S. Army Corps of Engineers administers the Section 404 permit program with oversight veto powers held by the U.S. EPA. The U.S. EPA, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service provide advice on the environmental impacts of proposed projects. National Park Service activities associated with wetlands are managed under Executive Order 11990, discussed later in this section.

It was the 1987 amendment to the Clean Water Act that finally established a stringent nonpoint source control mandate. Subsequent amendments further developed this mandate by requiring that states develop regulatory controls over nonpoint sources of pollution and over stormwater runoff from industrial, municipal, and construction activities. Many of the National Park Service's construction activities are regulated by the Clean Water Act under the stormwater permitting requirements.

Endangered Species Act of 1973

The Endangered Species Act requires the National Park Service to identify and promote the conservation of all federally listed endangered, threatened, or candidate species within any park unit boundary. This act requires all entities using federal funding to consult with the Secretary of Interior on activities that potentially impact endangered flora and fauna. It requires agencies to protect endangered and threatened species as well as designated critical habitats. While not required by legislation, it is the policy of the National Park Service to also identify state and locally listed species of concern and support the preservation and restoration of those species and their habitats.

Safe Drinking Water Act of 1974 and Amendments of 1996

This act directs the U.S. EPA to publish and enforce regulations on maximum allowable contaminant levels in drinking water. The act requires the EPA to issue regulations establishing national primary drinking water standards. Primary enforcement responsibilities lie with the states. The act also protects underground sources of drinking water, with primary enforcement responsibilities again resting with the states. Federal agencies having jurisdiction over public water systems must comply with all requirements to the same extent as any non-governmental entity.

The National Park Service must comply with state regulations regarding the construction, operation, and monitoring of its public water-supply system. Important aspects of this act include the underground injection and wellhead protection programs. Specific agency guidance is available in National Park Service Director's Order 83: Public Health (National Park Service 2000).

The 1996 amendments to the Safe Drinking Water Act initiated a new era in cost-effective protection of drinking water quality, state flexibility, and citizen involvement. Source water assessment and protection programs, provided under these amendments, offer tools and opportunities to build a prevention barrier to drinking water contamination. Source water protection means preventing contamination and reducing the need for treatment of drinking water supplies. Source water protection also means taking positive steps to manage potential sources of contaminants and contingency planning for the future by determining alternative sources of drinking water.

Redwood National Park Act of 1978

In 1978 an act expanding Redwood National Park further amended the general authorities of the National Park Service to mandate that all park system units be managed and protected "in light of the high public value and integrity of the national park system." Furthermore, no activities should be undertaken "in derogation of the values and purposes for which these various areas have been established," except where specifically authorized by law or as may have been or shall be directly and specifically provided for by Congress. Thus, by amending the general Authorities Act of 1970, this act reasserted system-wide the high standard of protection prescribed by Congress in the Organic Act.

Government Performance and Results Act of 1993

The Government Performance and Results Act of 1993 is the primary legislative framework through which agencies are required to set strategic goals, measure performance, and report on the degree to which goals were met. The intent of the Act is to improve public confidence in federal agency performance by holding agencies accountable for achieving program results and improving Congressional decision-making by clarifying and stating program performance goals, measures, and costs. It requires each federal agency to develop a Strategic Plan (five-year timeframe) that includes a mission statement, long-term strategic goals, and a description of how those goals are to be met through human, capital, information, and other resources. Under the Government Performance and Results Act, Strategic Plans are the basis for setting annual goals for programs and for measuring the performance of those programs.

As required by the Government Performance and Results Act, the National Park Service developed a service-wide Strategic Plan, with each park, program, and office subsequently developing its own Strategic Plan. The service-wide Strategic Plan includes the National Park Service mission, mission goals, long-term goals, and external analyses, providing the framework and direction for the entire National Park Service. Developed with public meetings and questionnaires, consultations with the Office of Management and Budget, Congress, and the Department of the Interior, it defines success for the National Park Service and shows service-wide direction. It builds on previous planning efforts and the contributions of many people within and outside of the National Park Service.

Park Strategic Plans must be based on the service-wide Strategic Plan, incorporating and reporting on progress toward meeting the service-wide mission goals and long-term goals. At the park strategic planning level, analysis will be focused on understanding the park's capability to set and meet long-term goals through a budget and human resource assessment. Managers will consider how each aspect of the park's mission goals might be pursued in the foreseeable future, and the answers to that question will determine the park's workload, budget, and staffing priorities for the next five years.

Ideally, the park Strategic Plan will tier from the GMP, building on the mission, mission goals, and management prescriptions included in that plan, and revising them to be stated as outcomes, if necessary. Although it shares some elements in common with a GMP, a park Strategic Plan will not be a substitute for a GMP because it does not reflect the comprehensive resource analysis, consultation, and compliance required for GMPs. Through strategic planning, park staffs will continuously reevaluate the adequacy of the park's GMP as a foundation for addressing issues, and they may identify the need for a new or revised GMP. Should a park decide, through its strategic planning process, that a major shift in activity emphasis is needed, then the Strategic Plan will identify the need for a new GMP or a GMP addendum or amendment. The GMP will be the appropriate vehicle for compliance on the associated social, environmental, and economic impacts. Strategic Plans may also identify the need for more detailed implementation documents. Such was the case for this Water Resources Management Plan that was an identified need in a previous (prior to 2001) park Strategic Plan.

The Strategic Plan for Richmond NBP for the 2001 to 2005 timeframe identifies four park mission goals. Within these mission goals, 21 long-term (5 years) goals and annual goals were established. Each long-term goal has an established realistic and achievable condition. Under the goal category of Preserve Park Resources, there are three long-term, natural resource issues: exotic species; threatened and endangered species and native species of special concern; and water quality. This Water Resources Management Plan provides management recommendations that address these issues. Additionally, the plan provides information on other water resource issues for which goals may be developed in future strategic plans.

Work plans are established for each annual goal. The annual work plan is not a comprehensive listing of all the activities, programs, or functions involved in the operation of Richmond NBP, but rather a realistic and representative subset indicating annual progress toward achieving long-term goals. Annual goals and work plans are contained in a separate, internal document.

National Parks Omnibus Management Act of 1998

Recognizing the ever increasing societal pressures being placed upon America's unique natural and cultural resources contained in the national park system, this act attempts to improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the national park system by:

- assuring that management of units of the national park system is enhanced by the availability and utilization of a broad program of the highest quality science and information;
- authorizing the establishment of cooperative agreements with colleges and universities and the establishment of cooperative study units to conduct multi-disciplinary research and develop integrated information products on the resources of the national park system;

- undertaking a program of inventory and monitoring of national park system resources to establish baseline information and to provide information on the long-term trends in the condition of national park system resources; and
- taking such measures as are necessary to assure the full and proper utilization of the results of scientific study for park management decisions. In each case in which an action undertaken by the National Park Service may cause a significant adverse effect on a park resource, the administrative record shall reflect the manner in which unit resource studies have been considered. The trend in the condition of resources of the national park system shall be a significant factor in the annual performance.

Executive Order for Floodplain Management (E.O. 11988)

The objective of E.O. 11988 (Floodplain Management) is "… to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." For non-repetitive actions, the E.O. states that all proposed facilities must be located outside the limits of the 100-year floodplain. If there were no practicable alternative to construction within the floodplain, adverse impacts would be minimized during the design of the project. National Park Service guidance pertaining to this E.O. can be found in Director's Order #77-2, Floodplain Management (currently under draft review). It is National Park Service policy to recognize and manage for the preservation of floodplain values, minimize potentially hazardous conditions associated with flooding, and adhere to all federally mandated laws and regulations related to the management of activities in flood-prone areas. Particularly, it is the policy of the National Park Service to:

- restore and preserve natural floodplain values;
- avoid to the extent possible, the long- and short-term environmental impacts associated with the occupancy and modification of floodplains, and avoid direct and indirect support of floodplain development wherever there is a practicable alternative;
- minimize risk to life and property by design or modification of actions in floodplains, utilizing non-structural methods when possible, where it is not otherwise practical to place structures and human activities outside of the floodplain; and,
- require structures and facilities located in a floodplain to have a design consistent with the intent of the Standards and Criteria of the National Flood Insurance Program (44 CFR 60).

Executive Order for Wetlands Protection (E.O. 11990)

This E.O. (entitled "Protection of Wetlands") requires all federal agencies to "minimize the destruction, loss or degradation of wetlands, and preserve and enhance the natural and beneficial values of wetlands" (Goldfarb 1988). Unless no practical alternatives exist, federal agencies must avoid activities in wetlands that have the potential to adversely affect the integrity of the ecosystem. National Park Service guidance for compliance with E.O. 11990 can be found in Director's Order #77-1 and Procedural Manual #77-1, "Wetlands Protection." In particular, it is the policy of the National Park Service to:

- avoid to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands;
- preserve and enhance the natural and beneficial values of wetlands;
- avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative;
- adopt a goal of no net loss of wetlands and strive to achieve a longer-term goal of net gain of wetlands servicewide;
- conduct or obtain parkwide wetland inventories to help assure proper planning with respect to management and protection of wetland resources;
- use "Classification of Wetlands and Deepwater Habitats of the United States " (Cowardin *et al.* 1979) as the standard for defining, classifying and inventorying wetlands;
- employ a sequence of first avoiding adverse wetland impacts to the extent practicable; second, minimizing impacts that could not be avoided; and lastly, compensating for remaining unavoidable adverse wetland impacts at a minimum 1:1 ratio via restoration of degraded wetlands;
- prepare a Statement of Findings to document compliance with Director's Order #77-1 when the preferred alternative addressed in an environmental assessment or environmental impact statement will result in adverse impacts on wetlands; and,
- restore natural wetland characteristics or functions that have been degraded or lost due to previous or ongoing human activities, to the extent appropriate and practicable.

National Park Service Management Policies and Guidelines

The National Park Service Management Policies (National Park Service 2001) provide broad policy guidance for the management of units of the national park system. Topics include park planning, land protection, natural and cultural resource management, wilderness preservation and management, interpretation and education, special uses of the parks, park facilities design, and concessions management.

With respect to water resources, it is the policy of the National Park Service to determine the quality of park surface and ground water resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks. In particular the National Park Service will work with appropriate governmental bodies to obtain the highest possible standards available under the Clean Water Act for protection of park waters; take all necessary actions to maintain or restore the quality of surface and ground waters within the parks consistent with the Clean Water Act and all applicable laws and regulations; and, enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of park water resources.

The National Park Service also will manage watersheds as complete hydrologic systems, and will minimize human disturbance to the natural upland processes that deliver water, sediment and woody debris to streams. The National Park Service will manage streams to protect stream processes that create habitat features such as floodplains, riparian systems, woody debris accumulations, terraces, gravel bars, riffles and pools.

The National Park Service will achieve the protection of watershed and stream features primarily by avoiding impacts to watershed and riparian vegetation and by allowing natural fluvial processes to proceed unimpeded. When conflicts between infrastructure (such as bridges) and stream processes are unavoidable, park managers will first consider relocating or redesigning facilities, rather than manipulating streams. Where stream manipulation is unavoidable, managers will use techniques that are visually non-obtrusive and that protect natural processes to the greatest extent practicable.

Additionally, natural shoreline processes (such as erosion, deposition, dune formation, and shoreline migration) will be allowed to continue without interference. Where human activities or structures have altered the nature or rate of natural shoreline processes, the National Park Service will investigate alternatives for mitigating the effects of such activities or structures. The National Park Service will comply with the provisions of Executive Order 11988 and state coastal zone management plans prepared under the Coastal Zone Management Act.

Recommended procedures for implementing service-wide policy are described in the National Park Service guideline series. The guidelines most directly pertaining to actions affecting water resources include:

> Director's Order #2: Park Planning;
> Director's Order #12: Conservation Planning, Environmental Impact
> Analysis, and Decision-making;
> Director's Order #77-1: Wetland Protection;
> Director's Order #77-2: Floodplain Management (under draft review);
> Director's Order #83: Public Health;
> NPS-75: Natural Resource Inventory and Monitoring; and
> NPS-77: Natural Resources Management.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

This act was enacted in 1980 and is commonly referred to as Superfund. The act creates a federal Superfund to clean up uncontrolled or abandoned hazardous waste sites as well as accidents, spills and other emergency releases of pollutants. The act contains an extensive list of hazardous substances that are subject to release reporting regulations. The National Response Center must be notified immediately by the person in charge of a vessel or facility when there is a release of any environmental media of a designated hazardous substance exceeding the predefined reportable quantity within any 24-hr period. The reporting quantities are determined on the basis of aquatic toxicity, reactivity, chronic toxicity, and carcinogenicity, with possible adjustments based upon biodegradation, hydrolysis, and photolysis.

Resource Conservation and Recovery Act (RCRA)

This act, enacted in 1976, establishes a regulatory structure for handling, storage, treatment, and disposal of solid and hazardous wastes. Many products and materials are regulated under this act, including commercial chemical products; manufactured chemical intermediates; contaminated soil, water, or other debris resulting from the cleanup of a spill into water or on dry land; and containers and inner liners of the containers used to hold waste or residue.

Executive Order for Invasive Species (E.O. 13112)

Signed in 1999, this E.O. complements and builds upon existing federal authority to aid in the prevention and control of invasive species.

Chesapeake Bay Agreement

In 1983 and 1987, the states of Virginia, Maryland, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission and the U.S. EPA, representing the federal government, signed historic agreements that established the Chesapeake Bay Program partnership to protect and restore the Chesapeake Bay's ecosystem. The full Agreement can be found at < http://www.chesapeakebay.net/agreement.htm >. The Agreement has several commitments, which can be summarized as follows:

1) Living resource protection and restoration, which has a goal to restore, enhance and protect the finfish, shellfish and other living resources, their habitats and ecological relationships to sustain all fisheries and provide for a balanced ecosystem;
2) Vital habitat protection and restoration, which has a goal to preserve, protect and restore those habitats and natural areas that are vital to the survival and diversity of the living resources of the Bay and its rivers;
3) Water quality protection and restoration, which has a goal to achieve and maintain the water quality necessary to support the aquatic living resources of the Bay and its tributaries and to protect human health;
4) Sound land use, which has a goal to develop, promote and achieve sound land use practices, which protect and restore watershed resources and water quality, maintain reduced pollutant loadings for the Bay and its tributaries, and restore and preserve aquatic living resources; and
5) Stewardship and community engagement, which has a goal to promote individual stewardship and assist individuals, community-based organizations, businesses, local governments and schools to undertake initiatives to achieve the goals and commitments of this agreement.

Specific to the commitment—vital habitat protection and restoration—are sections pertaining to watersheds, wetlands, and forests that may have implications for management of Richmond NBP units:

Watersheds

- By 2001, each jurisdiction will develop guidelines to ensure the aquatic health of stream corridors. Guidelines should consider optimal surface and groundwater flows.
- By 2002, each jurisdiction will work with local governments and communities that have watershed management plans to select pilot projects that promote stream corridor protection and restoration.
- By 2003, include in the "State of the Bay Report," and make available to the public, local governments and others, information concerning the aquatic health of stream corridors based on adopted regional guidelines.
- By 2004, each jurisdiction, working with local governments, community groups and watershed organizations, will develop stream corridor restoration goals based on local watershed management planning.
- By 2010, work with local governments, community groups and watershed organizations to develop and implement locally supported watershed management plans in two-thirds of the Bay watershed covered by this Agreement. These plans would address the protection, conservation and restoration of stream corridors, riparian forest buffers and wetlands for the purposes of improving habitat and water quality, with collateral benefits for optimizing stream flow and water supply.

Wetlands

- Achieve a no-net loss of existing wetlands acreage and function in the signatories' regulatory programs.
- By 2010, achieve a net resource gain by restoring 25,000 acres of tidal and non-tidal wetlands. To do this, we commit to achieve and maintain an average restoration rate of 2,500 acres per year basin wide by 2005 and beyond. We will evaluate our success in 2005.
- Provide information and assistance to local governments and community groups for the development and implementation of wetlands preservation plans as a component of a locally based integrated watershed management plan. Establish a goal of implementing the wetlands plan component in 25 percent of the land area of each state's Bay watershed by 2010. The plans would preserve key wetlands while addressing surrounding land use so as to preserve wetland functions.
- Evaluate the potential impact of climate change on the Chesapeake Bay watershed, particularly with respect to its wetlands, and consider potential management options.

Forests

- By 2002, ensure that measures are in place to meet our riparian forest buffer restoration goal of 2,010 miles by 2010. By 2003, establish a new goal to expand buffer mileage.
- Conserve existing forests along all streams and shorelines.
- Promote the expansion and connection of contiguous forests through conservation easements, greenways, purchase, and other land conservation mechanisms.

Agreement of Federal Agencies on Ecosystem Management in the Chesapeake Bay

In 1994, the Secretary of the Interior and the Director of the National Park Service joined in signing the *Agreement of Federal Agencies on Ecosystem Management in the Chesapeake Bay*. This agreement committed the National Park Service to work together with the states, federal agencies and other Chesapeake Bay Program partners to manage the Chesapeake Bay watershed as a cohesive ecosystem. On the forefront of a growing national watershed protection trend, the Chesapeake Bay Executive Council's *Adoption Statement on Riparian Forest Buffers* sets ambitious goals for riparian buffer protection to further both nutrient-reduction and habitat-restoration goals. Goals of the Executive Council include the following:

1) To assure, to the extent feasible, that all streams and shorelines will be protected by a forested or other riparian buffer;

2) To conserve existing forests along all streams and shorelines; and

3) To increase the use of all riparian buffers and restore riparian forests on 2,010 miles of stream and shoreline in the watershed by 2010, targeting efforts where they will be of greatest value to water quality and living resources.

In response, the National Park Service developed a Chesapeake Bay *Riparian Buffer Protection Plan* (National Park Service 1998b) to provide appropriate guidance for riparian buffer planning. Through this plan, National Park Service units within the Chesapeake Bay watershed are required to assure, to the extent feasible, that a forested or other riparian buffer protects all streams and shorelines on the 1,128 miles of perennial and intermittent stream corridors that exist within the National Park Service units within the Chesapeake Bay watershed. In addition to conserving the existing buffers, the National Park Service will seek opportunities to restore or improve an additional 35 miles of riparian buffer within its units within the watershed (National Park Service 1998b).

COMMONWEALTH OF VIRGINIA STATUTES AND DESIGNATIONS

The State Water Control Board promulgates Virginia's water regulations, including regulation of permits, permit fees, ground-water management, ground-water withdrawal and petroleum storage tanks. The Virginia Department of Environmental Quality (DEQ) administers the federal Clean Water Act and enforces state laws to improve the quality of Virginia's streams, rivers, bays and ground water for aquatic life, human health and other water uses. Permits that take into account physical, chemical, and biological standards for water quality are issued to businesses, industries, local governments, and individuals. Specifically, the purposes of the Virginia DEQ are as follows:

1) To assist in the effective implementation of the Constitution of Virginia by carrying out state policies aimed at conserving the Commonwealth's natural resources and protecting its atmosphere, land and waters from pollution.

2) To coordinate permit review and issuance procedures to protect all aspects of Virginia's environment.

3) To enhance public participation in the regulatory and permitting processes.

4) To establish and effectively implement a pollution prevention program to reduce the impact of pollutants on Virginia's natural resources.

5) To establish procedures for, and undertake, long-range environmental program planning and policy analysis.

6) To conduct comprehensive evaluations of the Commonwealth's environmental protection programs.

7) To provide increased opportunities for public education programs on environmental issues.

8) To develop uniform administrative systems to ensure coherent environmental policies.

9) To coordinate state reviews with federal agencies on environmental issues, such as environmental impact statements.

10) To promote environmental quality through public hearings and expeditious and comprehensive permitting, inspection, monitoring and enforcement programs, and provide effective service delivery to the regulated community.

11) To advise the Governor and General Assembly, and, on request, assist other officers, employees, and public bodies of the Commonwealth, on matters relating to environmental quality and the effectiveness of actions and programs designed to enhance that quality.

12) To ensure that there is consistency in the enforcement of the laws, regulations and policies as they apply to holders of permits or certificates issued by the Department, whether the owners or operators of such regulated facilities are public sector or private sector entities.

This section of the Water Resources Management Plan lists statutes and designations of the Commonwealth of Virginia that may be pertinent to Richmond NBP.

Surface Water Management of 1989

The Surface Water Management Act of 1989 and associated regulations apply a principle similar to ground-water management to areas where surface-water resources have a history of low-flow conditions that threaten important instream and off-stream uses. The Commonwealth has the responsibility to ensure that adequate surface flow of water in streams is maintained at levels that allow for the variety of potential uses, including minimum flows during periods of drought, assimilation of treated wastewater, and support of aquatic and other water-dependent wildlife.

The Virginia DEQ's surface-water withdrawal permit program became effective June 3, 1992. As needed, the Virginia DEQ designates surface-water management areas throughout the state. Each area is declared by a separate regulation that establishes a low water flow level for streams, below which permit limits for withdrawals from the streams become effective.

Water withdrawals of 300,000 or more gallons per month in a surface-water management area are required to have a surface-water withdrawal permit if new, or to have a surface-water withdrawal certificate to continue withdrawing surface water. The requirements for permits and certificates will include a conservation plan to be activated during low-flow conditions in the surface-water body.

Ground Water Management Act of 1992

Under the Ground Water Management Act of 1992, Virginia manages ground water through a program regulating the withdrawals in certain areas called ground-water management areas. The General Assembly determined that, pursuant to the Groundwater Act of 1973, the continued, unrestricted usage of ground water is contributing and will contribute to pollution and shortage of ground water, thereby jeopardizing the public welfare, safety and health. It is the purpose of this Act to recognize and declare that the right to reasonable control of all ground water resources within the Commonwealth belongs to the public and that in order to conserve, protect and beneficially utilize the ground water of the Commonwealth and to ensure the public welfare, safety and health, provision for management and control of ground water resources is essential. Those wishing to withdraw 300,000 gallons per month or more within a ground-water management area must apply for and receive a ground-water withdrawal permit. Currently, there are two ground-water management areas in the state: the Eastern Shore and Eastern Virginia.

Virginia Water-Quality Improvement Act of 1997

The purposes of this act are to encourage and promote nonpoint source pollution control and prevention, including nutrient control and prevention, for the: 1) protection of public drinking water supplies; 2) promotion of water resource conservation; 3) protection of existing high quality state waters and restoration of all other state waters to a condition or quality that will permit all reasonable beneficial uses and will support the propagation and growth of all aquatic life, including finfish and shellfish, which might reasonably be expected to inhabit them; 4) protection of all state waters from nonpoint source pollution; 5) prevention of any increase in nonpoint source pollution; 6) reduction of existing nonpoint source pollution; 7) attainment and maintenance of water quality standards established under subdivisions (3a) and (3b) of § 62.1-44.15; and 8) attainment of commitments made by the Commonwealth to water quality restoration, protection and enhancement including the goals of the Chesapeake Bay Agreement, as amended, all in order to provide for the health, safety and welfare of the present and future citizens of the Commonwealth.

Virginia Pollutant Discharge Elimination System (VPDES) Permits

The federal Clean Water Act enables the U.S. EPA to authorize the states to implement certain U.S. Environmental Protection Agency responsibilities. One of these responsibilities is the authority to issue NPDES permits. The U.S. EPA has authorized Virginia to issue NPDES permits. These permits, when issued by Virginia, are called Virginia Pollutant Discharge Elimination System (VPDES) permits. These permits carry the weight of both federal and state laws and regulations, and are enforceable under both state and federal authority. The Virginia DEQ requires VPDES permits for all point-source discharges (such as ditches or pipes) to surface waters by businesses, governments or individuals. The U.S. EPA maintains authority to review applications and permits for "major" dischargers, a distinction based on discharge quantity and content. The federal Water Quality Act of 1987 requires permits for certain industrial stormwater discharges and larger municipal stormwater systems. The Virginia DEQ regulates these stormwater discharges also through VPDES permits.

Stormwater Management Programs

The Virginia DEQ, the Virginia Department of Conservation and Recreation, and the Chesapeake Bay Local Assistance Department are coordinating three new and separate state programs that regulate the management of pollution carried by stormwater runoff. The programs were developed from separate state and federal laws passed to address surface-water contamination from land-use activities.

The federal Clean Water Act requires cities and urbanized counties having populations of more than 100,000 to develop stormwater management plans and obtain discharge permits for stormwater outfalls. In Virginia, this program is handled by the Virginia DEQ, which issues VPDES permits to localities. Companies must submit applications to the Virginia DEQ to ensure that stormwater discharges that enter streams directly from industrial facilities also are permitted.

The Virginia Stormwater Management Act enables local governments to establish management plans and adopt ordinances that require control and treatment of stormwater runoff to prevent flooding and contamination of local waterways. Local programs must meet or exceed the minimum standards contained in regulations. Under the act, state agencies must employ management practices whether or not the locality in which a state facility is to be located has a program.

The Chesapeake Bay Preservation Act establishes requirements for stormwater management within Chesapeake Bay preservation areas in all Tidewater localities. Under this legislation, each local government enforces its own program, which has been patterned on a model developed by the Chesapeake Bay Local Assistance Board and Department (see section entitled “Local Legislation and Designations.”)

Petroleum Storage Tanks Regulation

The Virginia DEQ regulates aboveground and underground petroleum storage tanks to ensure compliance with applicable regulations. The agency also manages all petroleum corrective action activities, including Corrective Action Plan permits for cleanup of underground storage tank leaks, and reimbursement of eligible costs to responsible parties.

Dredged Material

If a project requires a federal permit for discharges of dredged material into waterways or wetlands, or for other instream activities, the Virginia DEQ will review the project for issuance of a Virginia Water Protection permit, formerly called 401 certification.

State Water Control Law

It is the policy of the Commonwealth of Virginia and the purpose of this law to: 1) protect existing high quality state waters and restore all other state waters to such condition of quality that any such waters will permit all reasonable public uses and will support the propagation and growth of all aquatic life, including game fish, which might reasonably be expected to inhabit them; 2) safeguard the clean waters of the Commonwealth from pollution; 3) prevent any increase in pollution; 4) reduce existing pollution; 5) promote and encourage the reclamation and reuse of wastewater in a manner protective of the environment and public health; and 6) promote water resource conservation, management and distribution, and encourage water consumption reduction in order to provide for the health, safety, and welfare of the present and future citizens of the Commonwealth.

Virginia Water-Quality Standards (Statutory Authority: § 62.1-44.15(3a) of the Code of Virginia)

The State Water Control Board mandates the protection of existing high-quality state waters and provides for the restoration of all other state waters so they will permit reasonable public uses and will support the growth of aquatic life. The adoption of water-quality standards under Section 62.1-44.15(3a) of the law is one of the Virginia DEQ 's methods of fulfilling the law's purpose.

Water-quality standards consist of statements that describe water-quality requirements. They also contain numeric limits for specific physical, chemical, biological or radiological characteristics of water. These statements and numeric limits describe the quality of water necessary to meet and maintain uses such as swimming and other water-based recreation, public-water supply, and the propagation and growth of aquatic life.

The standards are intended to protect all state waters for recreation, wildlife, the growth of a balanced population of aquatic life, and the production of edible and marketable fish and shellfish. Through the protection of these uses, other uses such as industrial water supply, irrigation and navigation also are usually protected. Should additional standards be needed to protect other uses as dictated by changing circumstances or improved knowledge, they will be adopted.

Selected Virginia Water-Quality Standards are attached in Appendix B, and the entire document can be found at < http://www.deq.state.va.us/water/wqstnd.html >.

Water-Quality Monitoring and Reporting

The State Water Control Board shall develop the reports required by § 1313(d) (hereafter the 303(d) report) and § 1315(b) (hereafter the 305(b) report) of the Clean Water Act in a manner such that the reports will: 1) provide an accurate and comprehensive assessment of the quality of state surface waters; 2) identify trends in water quality for specific and easily identifiable geographically defined water segments; 3) provide a basis for developing initiatives and programs to address current and potential water quality impairment; 4) be consistent and comparable documents; and 5) contain accurate and comparable data that are representative of the state as a whole. The reports shall be produced in accordance with the schedule required by federal law, but shall incorporate at least the preceding five years of data. Data older than five years shall be incorporated when scientifically appropriate for trend analysis.

Wetlands Protection Act

The Wetlands Protection Act decrees that it is unlawful to excavate in a wetland. Further, on or after October 1, 2001, except in compliance with an individual or general Virginia Water Protection Permit, it shall also be unlawful to conduct the following activities in a wetland: 1) new activities to cause draining that significantly alters or degrades existing wetland acreage or functions, 2) filling or dumping, 3) permanent flooding or impounding, or 4) new activities that cause significant alteration or degradation of existing wetland acreage or functions.

Chesapeake Bay Preservation Act

In 1980, the legislatures of Virginia and Maryland established an organization that would coordinate the legislative planning efforts between the states in the restoration of the Chesapeake Bay. This organization was called the Chesapeake Bay Commission. In 1985, Pennsylvania joined the effort. Between 1983 and 1987, the Chesapeake Bay Commission, the U.S. EPA, Washington D.C., and separate representatives from Virginia, Maryland and Pennsylvania worked together to form an agreement of goals and priorities for cleaning up the Chesapeake Bay. Finally, in 1987, the Chesapeake Bay Agreement was signed and became the basis for each state to create and implement programs to clean up the Chesapeake Bay.

The Virginia General Assembly responded to the Chesapeake Bay Agreement by enacting the Chesapeake Bay Preservation Act in 1988. The Bay Act established a cooperative program between state and local government aimed at reducing nonpoint-source pollution. The Bay Act Program is designed to improve water quality in the Chesapeake Bay and its tributaries by requiring wise resource management practices in the use and development of environmentally sensitive land features. At the heart of the Bay Act is the idea that land can be used and developed in ways that minimize impact on water quality. The first sentence of the Bay Act serves as a theme for the entire statute: "Healthy state and local economies and a healthy Chesapeake Bay are integrally related; balanced economic development and water-quality protection are not mutually exclusive."

The Bay Act established the Chesapeake Bay Local Assistance Board and the Chesapeake Bay Local Assistance Department. The Chesapeake Bay Local Assistance Board developed regulations to provide guidance to localities creating their own Chesapeake Bay Preservation Programs. The Chesapeake Bay Local Assistance Department is the state agency that provides staff support to the Local Assistance Board in carrying out the requirements of the Bay Act. Major Department efforts in implementing the Bay Act include administering a competitive grants program for localities and planning districts, providing training for local government planners and engineers, and reviewing local comprehensive plans and ordinances for compliance. Once the Chesapeake Bay Local Assistance Board approved the regulations, each locality was given one year to establish its Chesapeake Bay Preservation Areas and enforcement mechanisms by incorporating development performance criteria through a separate ordinance or by revisions to existing zoning and subdivision ordinances.

As part of Virginia's efforts to help achieve the nutrient reduction goals for the Chesapeake Bay, nutrient reduction strategies are being developed for each of Virginia's Chesapeake Bay tributaries. The Virginia Department of Conservation and Recreation, working in cooperation with the Virginia DEQ and the Chesapeake Bay Local Assistance Department, is the lead agency for developing the nonpoint-source portion of Virginia's Tributary Strategies. The strategy for the Potomac and Shenandoah River basins has been written (the executive summary can be found at < http://www.state.va.us/~dcr/sw/ptexcsum.htm >). In addition, tributary strategies for the Rappahannock, York and James River basins have been completed (< http://www.deq.state.va.us/bay/strategies.htm >). A key to achieving the nutrient reduction goals for each of these rivers will be the involvement of local governments, Soil and Water Conservation Districts, planning district commissions, and local businesses and interest groups.

LOCAL LEGISLATION AND DESIGNATIONS

Local governments have programs to control some of the potential problems for surface water created by land-use changes. These include floodplain ordinances, stormwater management, and erosion- and sediment-control programs. Local governments also implement the Chesapeake Bay Preservation Act, which requires setbacks from streams to protect water quality. Some of these programs receive assistance from the local Soil and Water Conservation District (SWCD). The James River SWCD serves Chesterfield County (contact 804-957-6156); the Hanover-Caroline SWCD serves Hanover County (contact 804-537-5225); and the Henricopolis SWCD serves Henrico County (contact

804-501-5175; < http://www.co.henrico.va.us/sandw/ >). The SWCD conducts programs to help farmers prevent pollution by reducing farm runoff that can carry excess sediment, fertilizers, and pesticides into waterways. Water-quality protection is also required for forestry activities to protect streams from excess sediment resulting from the construction of logging roads or from crossing streams to harvest trees. In addition, SWCD staff administers nonpoint-source pollution control programs required by state law. These programs include erosion and sediment control, stormwater management, nutrient management, agricultural best management practices, shoreline erosion control, floodplain management, dam safety, and public beach conservation.

Local governments must amend their zoning ordinances, subdivision ordinances, and comprehensive plans to incorporate water-quality protection measures consistent with the Bay Act Regulations. The Bay Act Regulations use a "resource-based approach" that recognizes differences between various landforms and treats them differently. The Bay Act Regulations address nonpoint-source pollution by identifying and preserving certain lands called Chesapeake Bay Preservation Areas, Resource Protection Areas, and Resource Management Areas. By carefully managing land uses within these areas, local governments help reduce the water-quality impacts of nonpoint-source pollution and improve the health of the Chesapeake Bay. Local governments have flexibility to develop water-quality preservation programs that reflect unique local characteristics and embody other community goals.

The lands that make up Chesapeake Bay Preservation Areas are those that have the potential to impact water quality most directly. Chesapeake Bay Preservation Areas are lands "which, if improperly developed, may result in substantial damage to the water quality of the Chesapeake Bay and its tributaries." These lands include both Resource Protection Areas and Resource Management Areas. Local governments are required to map the natural features that must be considered in designating Chesapeake Bay Preservation Areas. Development in all Chesapeake Bay Preservation Areas must meet general performance criteria that are designed to reduce nonpoint-source pollution and/or protect sensitive lands from disturbance. These criteria include the following:

- preserve natural vegetation;
- minimize disturbance of land;
- minimize impervious cover such as paving;
- strictly control soil erosion during land clearing and construction;
- control stormwater runoff and its quality;
- pump out septic tanks once every five years;
- provide a reserve drainfield for septic tanks, which equals the waste treatment capacity of the primary drainfield;
- subject all development to site plan review; and
- control stormwater quality in agricultural and forested areas.

Resource Protection Areas are lands at or near the shoreline that have an intrinsic water-quality value due to the ecological and biological processes they perform. These lands may help to protect water quality or be easily damaged by the impacts of development.

Local governments must include tidal wetlands, certain nontidal wetlands, tidal shores, and other lands that are especially important to water quality in the Resource Protection Areas. A Resource Protection Area must also include a buffer area of 100 feet, measured from the landward side of these natural features.

Resource Management Areas are lands that protect the values of the Resource Protection Area. Improper development in these areas will have an adverse impact on water quality. Floodplains, highly erodible soils, steep slopes, highly permeable soils, other nontidal wetlands, and other lands necessary to protect water quality are to be considered by local governments in delineating Resource Management Areas. A Resource Management Area must be designated landward of and contiguous to all Resource Protection Areas.

LAND USE/ZONING

Many park management and resource protection issues are a result of the complex pattern of land ownership and land use within the watersheds associated with each park unit. The park owns land in Chesterfield, Hanover, and Henrico counties. Drewry's Bluff (39.5 acres) is in Chesterfield County. Beaver Dam Creek, Gaines' Mill, Cold Harbor, and the Garthright House (227 acres combined) are in Hanover County. Chickahominy Bluff, Malvern Hill/Glendale, and Fort Harrison (1,086 acres combined) are in Henrico County. The combined population of these three counties in 1990 was 490,461, with 209,274 in Chesterfield, 63,306 in Hanover, and 217,881 in Henrico (National Park Service 1996). By 2000, the combined population was 608,523, with 259,903 in Chesterfield, 86,320 in Hanover, and 262,300 in Henrico (< http://www.census.gov/main/www/cen2000.html >). This represents a growth rate of 24% in the three counties combined, with a 24% increase in Chesterfield, 36% in Hanover, and 20% in Henrico.

Current land use in all units of the park consists of a mixture of forest, agriculture, and managed meadows and lawns. On average, the units are approximately 85% forested. Agricultural areas exist at the Malvern Hill/Glendale unit (approximately 95 acres or 13% of its lands) and the Gaines' Mill unit (approximately 30%). In the Gaines' Mill unit, the agricultural areas are planted in a variety of crops, which have included hay, wheat, soybeans, millet, and other low-growing crops, depending on the season (Land and Community Associates 1999). The remaining acreage, 6% at Chickahominy Bluff, 2% at Beaver Dam Creek, 5% at Malvern Hill/Glendale, 18% at Fort Harrison, and 23% at Drewry's Bluff, consists of mowed meadows and lawn areas. The surrounding area outside of park boundaries generally consists of open uplands in agricultural use and wooded stream corridors with swampy bottomlands.

The Land Use Plan for Chesterfield County is presently under revision. However, the land on the west, south and east of Drewry's Bluff is zoned for heavy industrial development (James Bowling, County of Chesterfield, pers. comm. 2002). Heavy industrial refers to industry with outside operations, such as the asphalt plant, which exists directly to the west of the park. This type of development presently surrounds the unit, and additional development is expected to be minimal. However, the present level and type of land use is likely to impact the water quality in the watershed associated with this unit.

In 1990, the population of Hanover County was 63,306; population is projected to rise to 142,200 by 2020 (a 124% growth rate) (National Park Service 1996). The current Land Use Plan for Hanover County (Lee Garman, County of Hanover, pers. comm. 2000), called Vision 2017, zones the area north of Route 156 for phased suburban development, which would commence in the 2002-2007 timeframe (Figure 2 a-b). The phased suburban development in this area allows for low-density residential development (1-2 housing units per acre), once the water and sewer lines become available. Should this development occur to the full "build out" level allowed for by zoning, the Cold Harbor unit could be surrounded on the north, west, and east sides by low-density suburban development, which could have an impact on both water quantity and water quality. The 2.1-acre Garthright House portion of the park is surrounded on three sides by a 50.9-acre passive-use park being developed by Hanover County (National Park Service 1996).

Vision 2017 for Hanover County indicates that the area to the north, east and west of Beaver Dam Creek is zoned for medium (1-4 dwellings per acre) and high (4-15 dwellings per acre) density residential development and commercial development. As this type of development already exists in this area, future expansion will be limited. However, the present level of development is likely to impact both the quality and quantity of water in the watershed associated with this unit.

Vision 2017 zones the land south of Route 156 as "Agricultural," which limits future residential development to a maximum of one housing unit per 10 acres (Figure 2a). Rezoning to either "RC District" or "AR-6 District" could be approved by the county in the future. Both of these categories would allow for development to a maximum density of 1 unit per 6.25 acres. The difference is that the AR-6 District zoning allows for the traditional subdivision layout, where the minimum lot size is 6.25 acres, whereas RC District zoning allows clustering of development without prescribed minimum lot size as long as 70% of the land is deemed "open space" and a maximum density of 1 residence per 6.25 acres is maintained for the project. The present Agricultural zoning, or the rezoning to RC District or AR-6 District, would affect the land surrounding the Gaines' Mill unit and could potentially affect water quality. Agricultural land use can result in over-enrichment of nutrients and pesticides in surface and ground waters. As an example of effects of development, Schueler (1994) used a biodiversity metric (index) to measure the effect of the percentage of impervious surfaces in watersheds in urban areas in northern Virginia and southern Maryland and found that at percentages above 15%, the biodiversity in the stream was degraded (Figure 3). Furthermore, a U.S. EPA study found that of 29 aquatic or riparian species of herpetofauna found during a Maryland survey, only seven occurred in heavily urbanized areas (greater than 25% impervious land cover in the upstream watershed). Conversely, four species of salamanders never occurred in urbanized areas (greater than 3% impervious land cover) (< http://www.epa.gov/maia/assets/pdf/md-streams.pdf >).

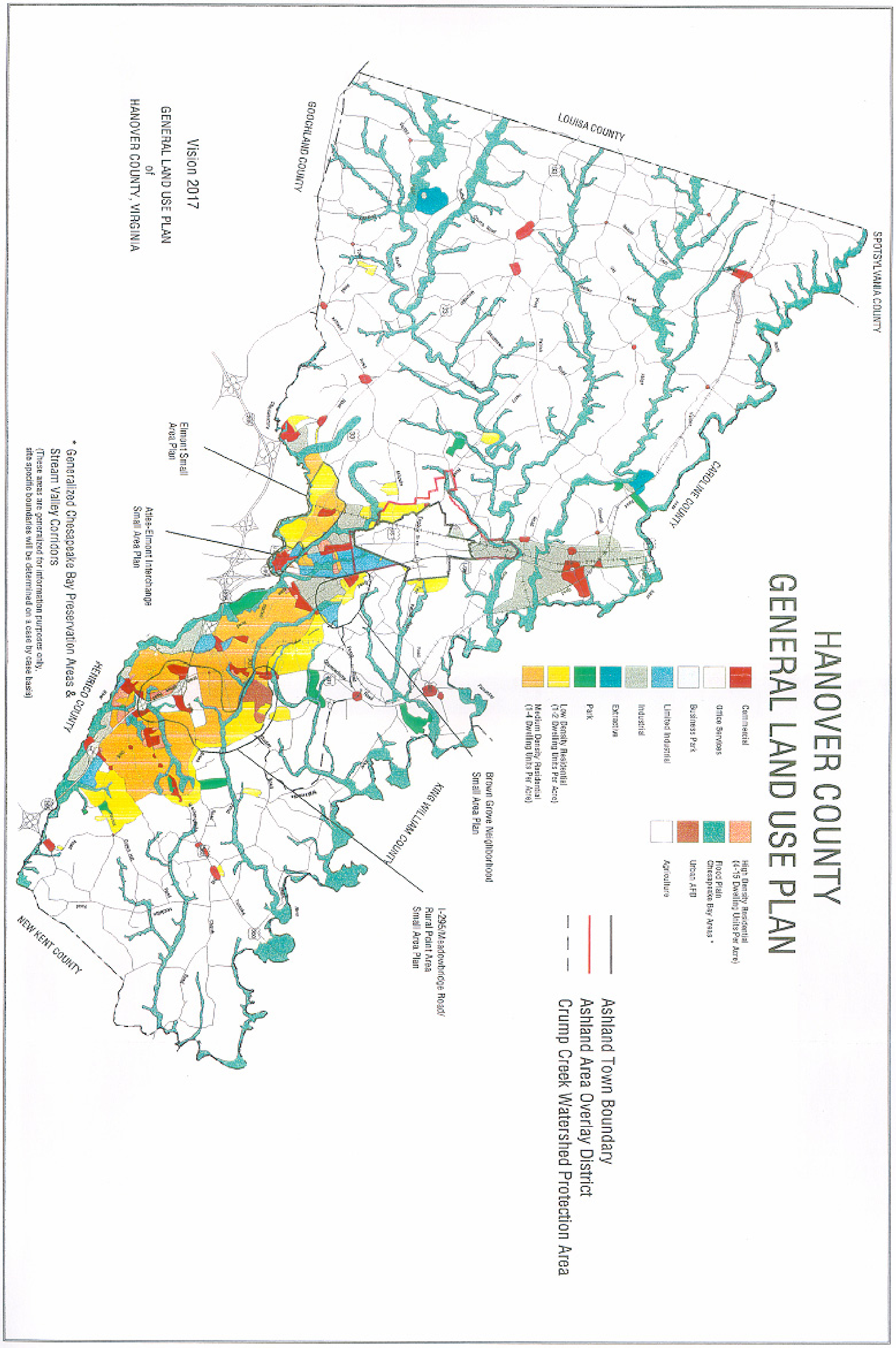

Figure 2a. Hanover County General Land Use Plan.

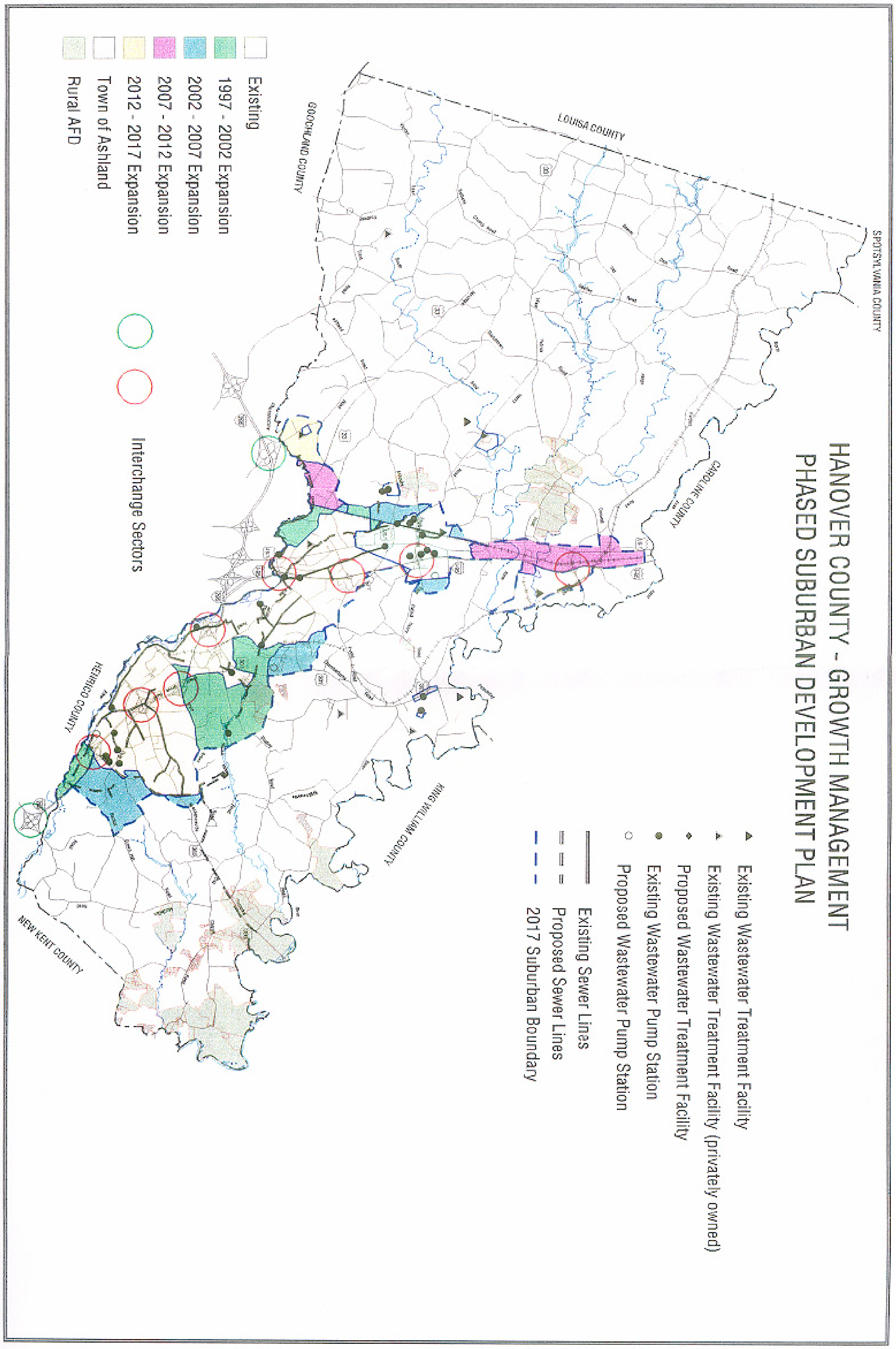

Figure 2b. Hanover County Growth Management Phased Surburban Development Plan.

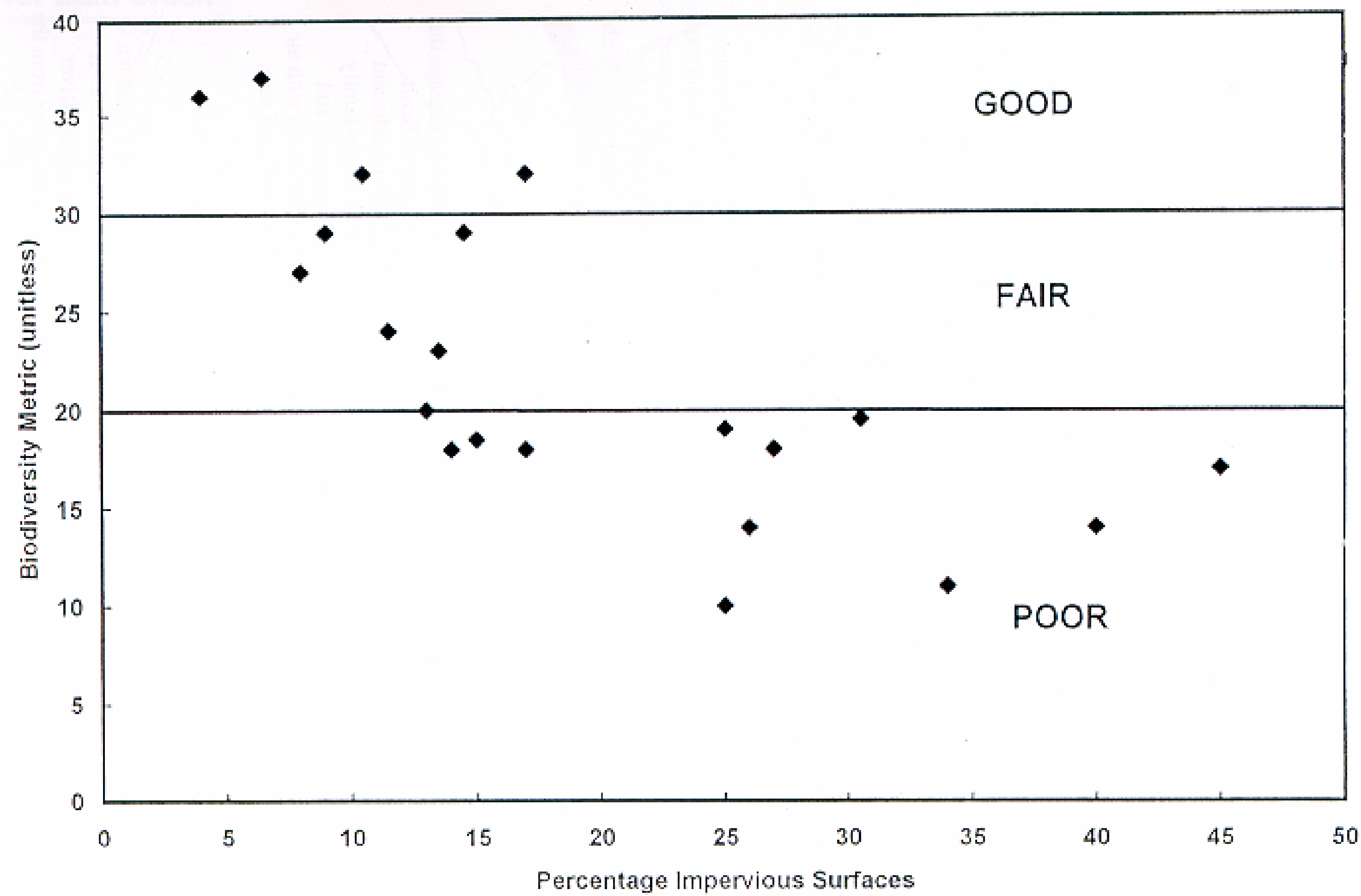

Figure 3. Relation of biodiversity metric to percentage of impervious surfaces in urban watersheds.

Hanover County also is in the early stages of developing a Historic Preservation Strategy, which could influence future zoning considerations in the county. This Water Resources Management Plan strongly encourages the park to take part in this effort, as the historical context of the lands ranges far beyond the present park boundary, and decisions made concerning surrounding land use will ultimately affect the water resources in the park.

Henrico 2010, the current Land Use Plan for Henrico County, indicates that the land on the east, south and west of the Chickahominy Bluff unit is zoned for Urban (3.4-6.8 dwellings per acre), Suburban 1 (1-2.4 dwellings per acre) and Suburban 2 (2.4-3.4 dwellings per acre) Residential, Office and Commercial Concentration. This area is defined as "existing," which means it is presently 90% developed. The land surrounding both the Fort Harrison and Malvern Hill/Glendale units are zoned for prime agriculture and rural residential (<1 dwelling per acre). Both areas are defined as "outlying area," which refers to its agricultural uses, large-tract ownership, and low-density residential uses. Any development in these areas would require major infrastructure improvements. Although additional development surrounding these three units is not likely, present land uses are likely to affect both the quantity and quality of water in the associated watersheds.

A comprehensive effort is underway to document resource values of the Chickahominy basin and learn more about how the health of the Chickahominy wetlands and waterways are related to the surrounding land use. The U.S. Fish and Wildlife Service has teamed up with state and federal agencies and university researchers to study the effects of people and natural forces changing the landscape in the Chickahominy watershed. With existing information and new research, they hope to identify key areas to focus public and private conservation efforts.

EXISTING RESOURCE CONDITIONS

The park's separation into 11 distinct units makes it seemingly impossible to manage the area as an ecological unit. Maintaining natural area characteristics is very difficult because of the small size of the units as well as the variation in land uses on adjacent private lands. These uses include extensively developed areas, such as single-family housing, apartment complexes, interstate highways and other major roadways, and industrial complexes. These activities have generated or exacerbated problems with air and water pollution, exotic plant infestation, and maintenance and protection of rare, threatened, or endangered plants and wildlife.

LOCATION AND HISTORICAL FEATURES

The Beaver Dam Creek unit is located approximately six miles northeast of downtown Richmond on Cold Harbor Road (State Route 156) near its intersection with I-295. It contains a short section of Beaver Dam Creek, a tributary of the Chickahominy River (Figure 4). This unit contains the site of Ellerson's Mill, which harnessed power from the adjacent creek, and remnants of the historic millrace. At this site in June 1862, the Confederates charged down the hill and across the creek to the waiting Union defenses,

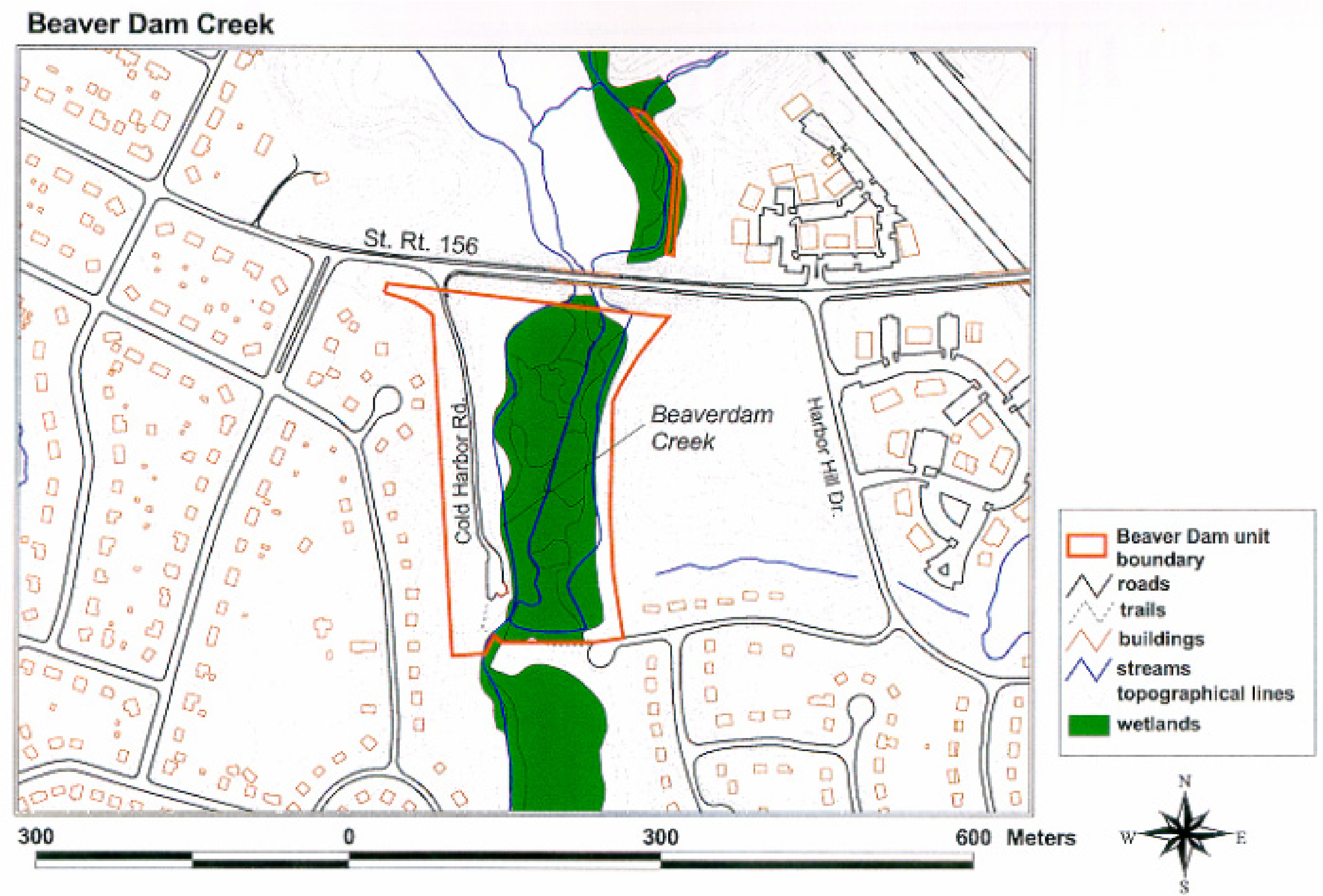

Figure 4. Topographic map of the Beaver Dam Creek unit.

who inflicted devastating casualties. The mill and its associated dam were used as a defensive position by the Union troops. A short interpretive trail and associated wayside exhibits lead across the creek down historic Cold Harbor Road to the mill site.

The Chickahominy Bluff unit lies five miles northeast of downtown Richmond on Mechanicsville Turnpike (State Route 360). A short park road immediately east of Route 360 accesses the unit and a small parking area. This site contains part of the city's outer defenses built in 1862. On June 26, 1862, it provided a strategic view of the Chickahominy River. It was from this point that the Confederate Army of Northern Virginia, under the command of General Robert E. Lee, initiated the Seven Days' Campaign. A short interpretive trail and associated wayside exhibits lead to an observation deck overlooking a portion of the unit, the Chickahominy River Valley, modern development, and high-voltage power lines (Figure 5).

The Cold Harbor unit is on the north side of two-lane State Route 156 between the Hanover Farms subdivision and the community of Old Cold Harbor and is accessed from State Route 156 via an auto tour road (Figure 6). Historical resources in the Cold Harbor unit include linear earthworks (8,812 yards), 655 associated holes and depressions, 9 artillery positions or emplacements and marked or volunteer trails (4,753 yards) (Michael Andrus, Richmond NBP, pers. comm. 2000). The potential for archeological resources exists throughout the entire site. The Garthright House lies on a 2.1-acre parcel of land on the south side of State Route 156 just east of the main Cold Harbor unit and across from Cold Harbor National Cemetery (Figure 6). The Garthright House, portions of which date to the 1700's, served as a Union field hospital during the Battle of Cold Harbor and later served as a Confederate hospital. The restored house is used as an exterior exhibit only. The parcel is surrounded on three sides by a 50.9-acre passive use park being developed by Hanover County. For this report, the Garthright House is included as part of the Cold Harbor unit.

The Drewry's Bluff unit is approximately 8 miles south of downtown Richmond and overlooks the James River. It is accessed via Fort Darling Road off of Bellwood Road. This unit contains a half-mile interpretive trail leading from the parking lot to Fort Darling and the strategic overlook used to protect Richmond from Union gunboats traveling up the river (Figure 7). A Union naval attack on Fort Darling failed in May 1862, as did a Union army advance in May 1864. This site was used as the Confederate Naval Academy and Marine Corps training facility during the war.

The Fort Harrison unit is approximately 8 miles southeast of downtown Richmond and includes a 6-mile long section of Battlefield Park Drive and Hoke Brady Road. It can be accessed via New Market (State Route 5), Mill, Varina or Kingsland Roads, or Osborne Turnpike. It is one of the most frequently visited units within Richmond NBP. The unit is a long narrow corridor of earthworks along Battlefield Park Drive, six fort sites, and a visitor's center/maintenance and residential area (Figure 8). The unit contains a series of fortifications (Forts Gilmer, Maury, Harrison, Hoke, and Johnson) built as part of the Confederate defenses of Richmond and connected by miles of breastworks. The Union

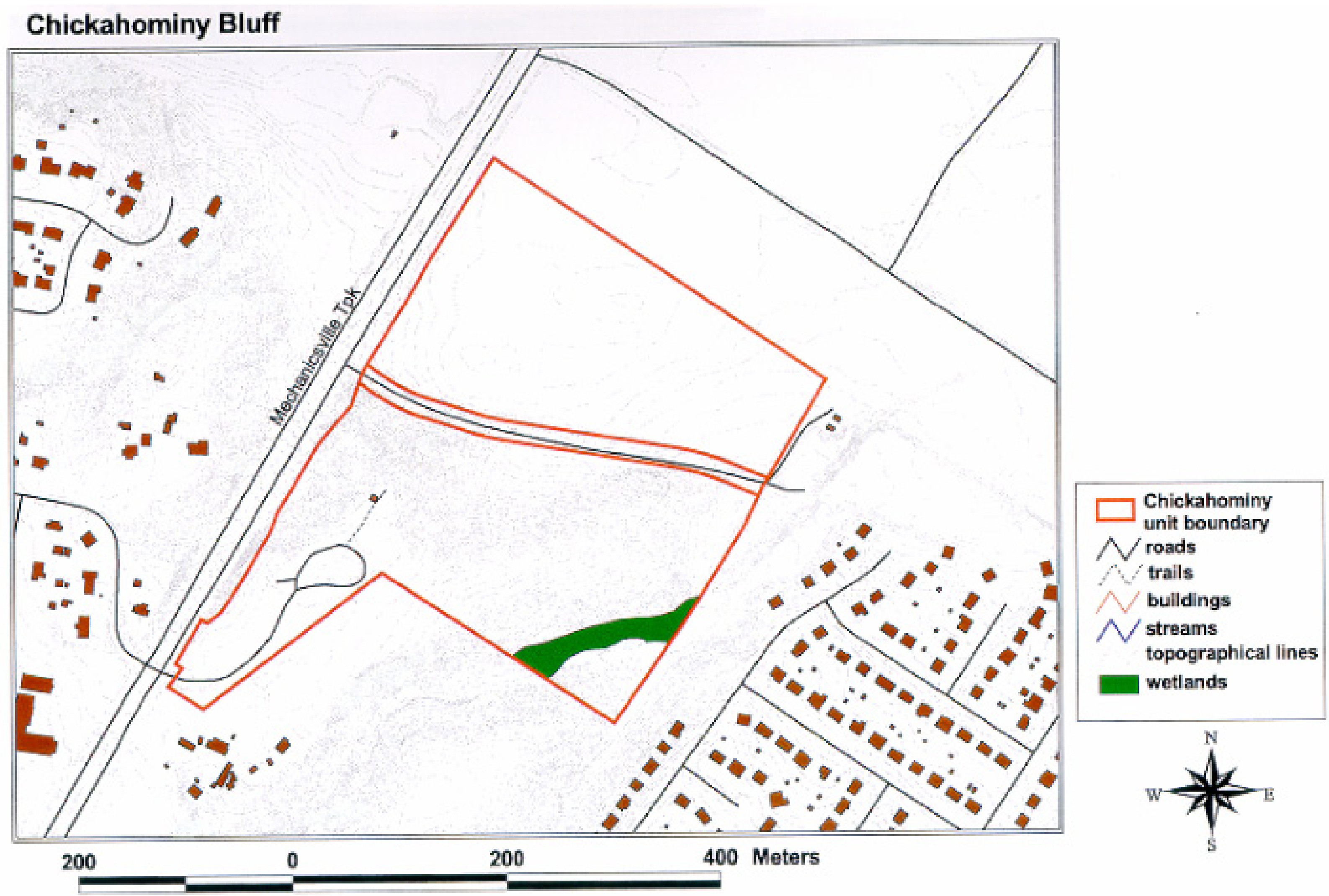

Figure 5. Topographic map of the Chickahominy Bluff unit.

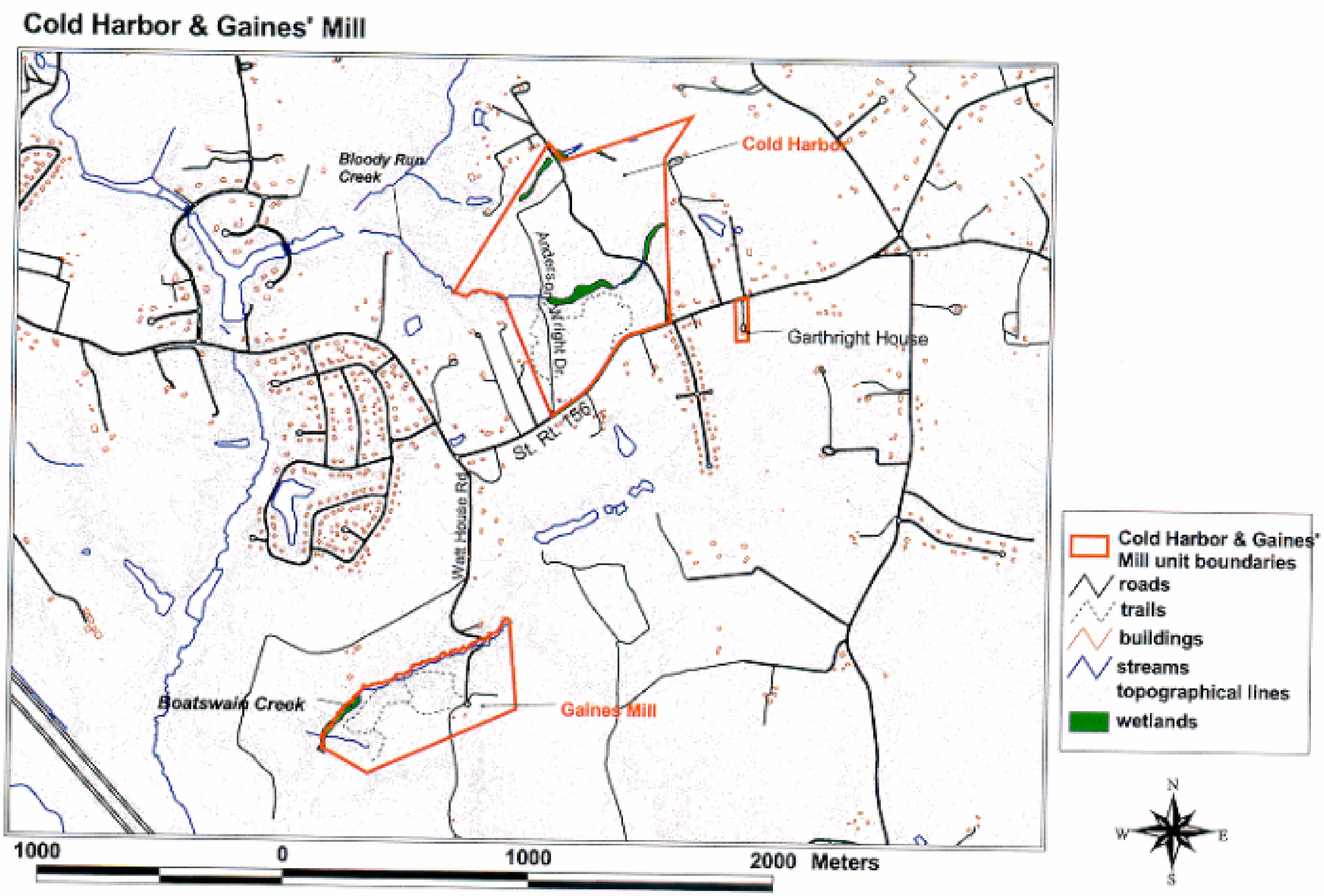

Figure 6. Topographic map of the Cold Harbor unit, the Garthright House, and the Gaines' Mill unit.

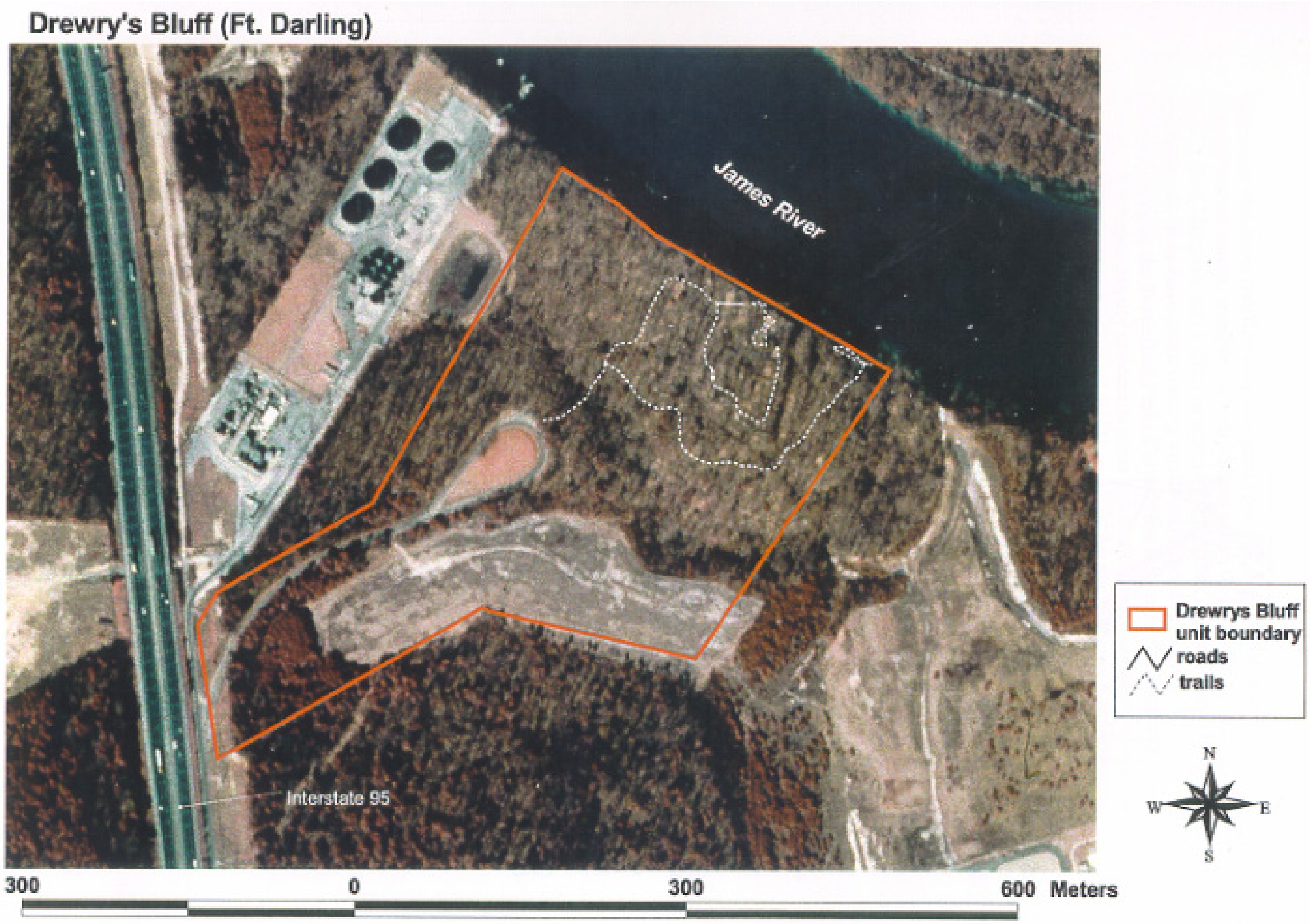

Figure 7. Topographic map of the Drewry's Bluff unit.

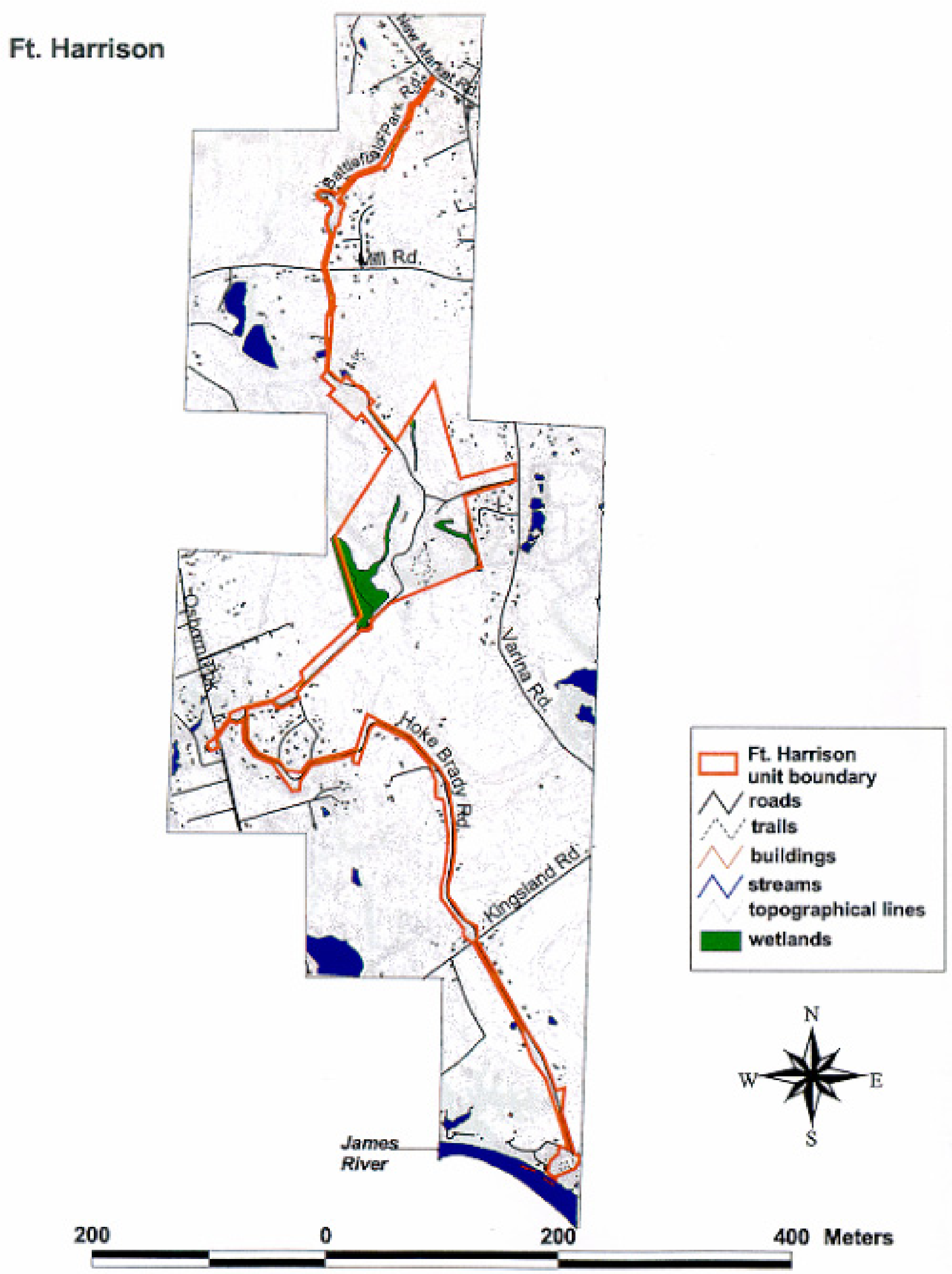

Figure 8. Topographic map of the Fort Harrison unit.

army captured these fortifications in September 1864, after which Fort Brady was added. A small visitor center, interpretive trail with an audio wayside exhibit, and picnic area exist at Fort Harrison, and a short interpretive trail exists at Fort Brady. Forts Gilmer, Johnson, and Hoke have small parking areas with wayside exhibits. A historic log structure built by the Battlefield Parks Corporation is near the Fort Harrison Visitor Center. Moderate-density residential areas and some agriculture surround the unit. The unit includes a national cemetery that is managed by the Veterans Administration.

The Gaines' Mill unit lies southwest of the Cold Harbor unit on the southern bank of Boatswain Creek, approximately 0.5 mile south of State Route 156 near the community of New Cold Harbor, and is accessed via Watt Farm Road (Figure 6). The Watt House, an 1830's restored structure, is situated within the boundaries of the Gaines' Mill unit and is used as an exterior exhibit only. Historical resources in the Gaines' Mill unit include rifle pits, potholes, a bridge and fill area, trenches and a trench complex, a breastworks area (linear ridge), and a mound; additionally, the area could contain battle-related deposits, defensive features, and graves and/or human remains (Land and Community Associates 1999).

The Malvern Hill and Glendale units are approximately 15 miles southeast of downtown Richmond on State Route 156 near its intersection with State Route 5. The units are accessible by either Carter's Mill Road or Willis Church Road (Figure 9). Malvern Hill contains a parking lot and interpretive shelter, which overlooks acres of cultural landscape including open field and cannon. At this site in July 1862 the Union Army stood in battle formation firing upon the charging Confederate troops forced by the land's topography to advance across an open field. An approximately two-mile interpretive loop trail begins at the shelter and meanders through open field and wooded areas. It guides visitors past the site of the outbuildings associated with the Crewes/Mettert House, to the remnants of Willis Methodist Church Parsonage, thought to be used as a field hospital during the Civil War, and the site of the historic West house. Farther north on Willis Church Road, visitor services and interpretive staff are available at the lodge inside the Glendale National Cemetery.

CLIMATE

The climate affecting Richmond NBP is typical for the east coast of the United States in general and the Virginia Piedmont and Coastal Plain in particular. The climate is characterized by warm, humid summers and generally mild winters, with little or no snowfall during some years (Land and Community Associates 1999). Average daytime summer temperatures reach 90° F, and winter daytime lows average 35° F. The annual average rainfall since 1962 is 43.5 inches, and the annual snowfall averages 14.2 inches between November and March (Land and Community Associates 1999).

PHYSIOGRAPHY AND GEOLOGY

All of the park units lie within the Atlantic Coastal Plain Physiographic Province, immediately east of the transition zone (the Fall Line) between the Piedmont and Atlantic

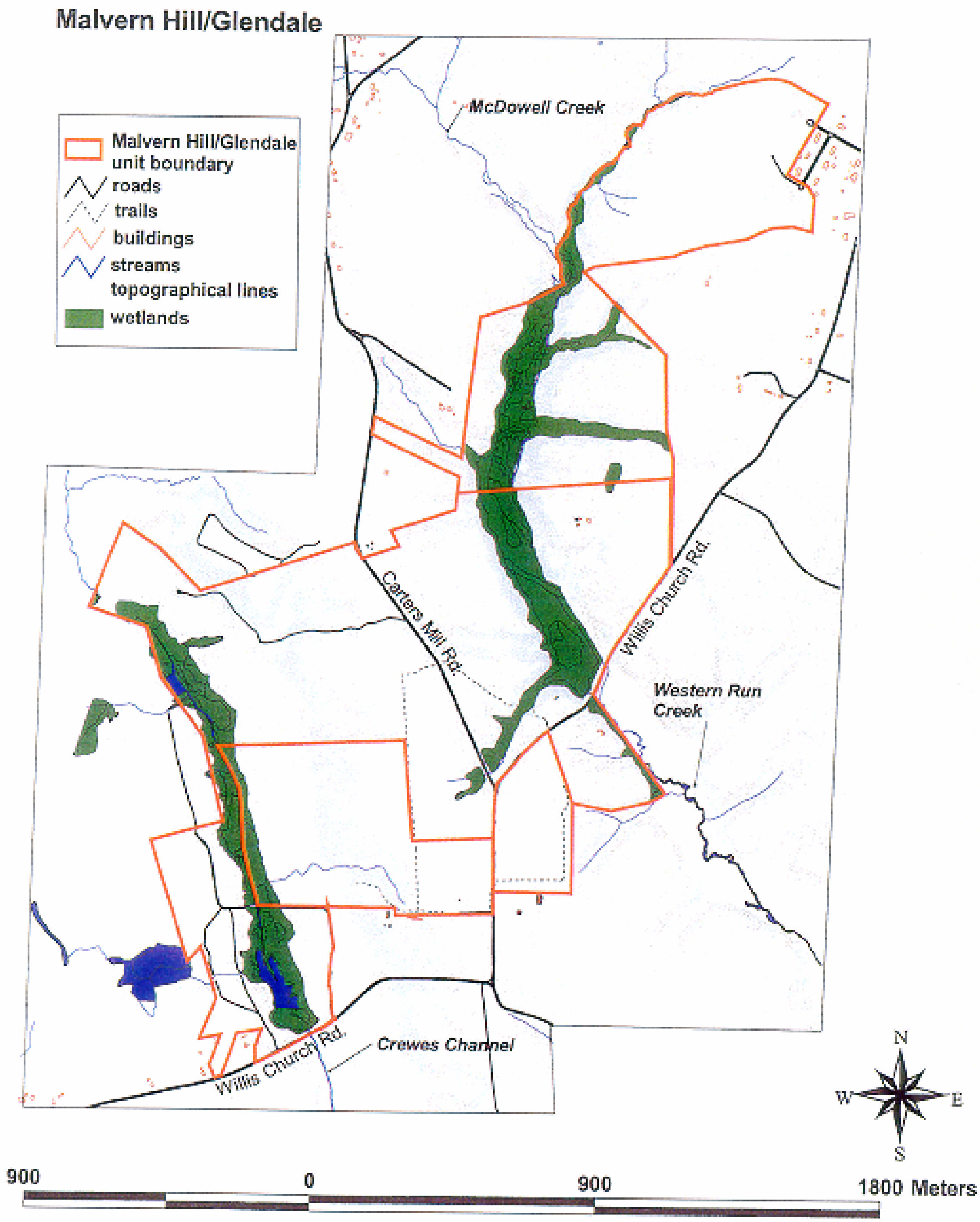

Figure 9. Topographic map of the Malvern Hill/Glendale units.

Coastal Plain Physiographic provinces. The Fall Line, which separates the two physiographic provinces, trends roughly north to south in this area. The Atlantic Coastal Plain Physiographic Province (hereinafter referred to as the Coastal Plain) comprises approximately 10,000 mi^2 in Virginia.

The Coastal Plain consists of Cretaceous- through Quaternary-age sediments that thicken eastward; at the Fall Line, the sediments are very thin, whereas at the Atlantic Ocean coastline, the sediments are over 5,000 feet thick (Meng and Harsh 1988). In general, Coastal Plain sediments consist of unconsolidated interbedded gravels, sands, silts, and clays (Meng and Harsh 1988).

The geology of the Richmond and Seven Pines 1:24,000-scale topographic quadrangles has been mapped by Daniels and Onuschak (1974), providing detailed mapping for the Beaver Dam Creek, Chickahominy Bluff, Cold Harbor, and Gaines' Mill units. Additional details on the geology of the Cold Harbor unit can be found in Inners *et al.* (1995). Detailed geologic mapping (at a scale of 1:24,000) does not exist for the Drewry's Bluff, Dutch Gap, or Roxbury topographic quadrangles, which encompass the Drewry's Bluff, Fort Harrison, and Malvern Hill/Glendale units, however some details on the geology of the Drewry's Bluff and Fort Harrison units can be found in Inners *et al.* (1995). Less detailed geologic mapping for the Drewry's Bluff, Fort Harrison, and Malvern Hill/Glendale units exists at a scale of 1:250,000 (Mixon *et al.* 1989).

The Beaver Dam Creek unit is predominantly underlain by recent alluvium of Beaver Dam Creek (Daniels and Onuschak 1974). The majority of this alluvium consists of organic and poorly sorted deposits ranging from clay to gravel (Daniels and Onuschak 1974). Older (Tertiary) clayey silt deposits are exposed along the eastern and western boundaries of the unit (Daniels and Onuschak 1974). Mixon *et al.* (1989) mapped this area as the Late Tertiary Chesapeake Group.

Three geologic units are exposed in the Chickahominy Bluff park unit. The highest elevations are underlain by undivided Late Tertiary – Early Quaternary upland sand and gravel deposits (Daniels and Onuschak 1974). The bluff is cut into underlying clayey silt deposits, also of Late Tertiary – Early Quaternary age, and the bottomlands are underlain by more recent alluvial deposits of the Chickahominy River (Daniels and Onuschak 1974). Mixon *et al.* (1989) mapped the clayey silt deposits as the Late Tertiary Chesapeake Group.

The Cold Harbor and Gaines' Mill units are situated on a dissected upland plain that consists of early Pliocene-age interbedded gravelly sand, sandy gravel, and fine-to-coarse-grained sand (Inners *et al.* 1995). Daniels and Onuschak (1974) describe these surficial sediments as fluvial clays, clayey silts, sands, and gravels. Marine-deposited clayey silts, partly fossiliferous, with firm, well-sorted basal sand underlie the surficial sediments at both sites. Mixon *et al.* (1989) mapped these surficial sediments as the Late Tertiary Chesapeake Group. At both sites, the creek bottomlands consist of recent alluvium, which comprises organic and poorly sorted fluvial deposits that range in size from clay to gravel (Daniels and Onuschak 1974).

The Cretaceous-age Potomac Formation and minor amounts of the Quaternary-age Charles City Formation (Mixon *et al.* 1989) underlie the Drewry's Bluff unit. The Potomac Formation is characterized by quartzofeldspathic fine to coarse sand, interbedded with massive sandy clay and silt (Mixon *et al.* 1989). The Potomac Formation forms the steep bluff at this park unit (Inners *et al.* 1995). The Charles City Formation consists of a discontinuous, thin cap of sand, silt, and clay (Mixon *et al.* 1989).

The Fort Harrison unit is underlain by the Quaternary-age Windsor Formation and the Tertiary age Bacon's Castle Formation (Mixon *et al.* 1989). The Windsor Formation consists of sand, gravel, silt, and clay (Mixon *et al.* 1989) with some glauconite (Inners *et al.* 1995). The Bacon's Castle Formation is subdivided and mapped as two units. The unit underlying the Fort Harrison unit is characterized by thick-bedded gravel, grading upward into sand and sandy and clayey silt (Mixon *et al.* 1989).

The Bacon's Castle Formation, as described above for the Fort Harrison unit underlies the higher elevations of the Malvern Hill and Glendale units. The Chesapeake Group is exposed on the steep slopes on the west side of the battlefield and on the slopes on the east side of the battlefield along Western Run (Mixon *et al.* 1989). The extreme western edge of the battlefield unit is underlain by the middle Pleistocene-age Chuckatuck Formation, a geologic unit containing sand, silt, and clay, with minor amounts of peat (Mixon *et al.* 1989).

HYDROGEOLOGY

The regional hydrogeology of the Coastal Plain Physiographic Province is controlled by the configuration of the Coastal Plain sediments, i.e., the sediments are interbedded in a more or less regular sequence of layers of high permeability alternating with layers of low permeability. The layers of high permeability, which are generally composed of sand and sandy sediments, transmit ground water readily and are known as aquifers. An aquifer is defined as a water-bearing geologic unit. The layers of low permeability, which are generally composed of clay and clayey sediments, do not transmit ground water readily and are called confining units, or aquitards. Aquifers that are located beneath or between aquitards are termed confined aquifers.

The surficial aquifer is composed of permeable geologic materials and extends downward from elevations at or near land surface to the top of the uppermost aquitard, or to bedrock along the western edge of the Coastal Plain. Because there is no upper confining unit, it is called an unconfined aquifer. This shallow ground water in the surficial aquifer supplies most of the water by seeps and springs to small streams and many wetlands. The top of the saturated zone, called the water table, is free to rise in response to recharge (i.e. precipitation) and fall in response to discharge (i.e. from drawdown induced by pumping from wells completed in the surficial aquifer, or by supplying water to streams). Pumping from wells completed in confined aquifers affects water levels in those aquifers to a greater extent than the affect on water levels in the surficial aquifer by pumping in wells completed there. In this report, water in a confined aquifer is referred to as deep ground water, and water in the surficial aquifer is referred to as shallow ground water. A generalized hydrogeologic section and direction of ground-water flow in the Coastal Plain Physiographic Province of Virginia (McFarland 1997) is shown in Figure 10.

The Beaver Dam Creek unit is underlain by bedrock at an estimated depth of 200 to 250 feet below sea level (Meng and Harsh 1988). The unconsolidated Potomac Formation sediments above the bedrock form a probable unconfined aquifer, though some confined or semi-confined zones within the Potomac Formation sediments may exist at depth. Depth to ground water is consistently shallow, as this area serves as a ground-water discharge zone.

The Chickahominy Bluff unit is underlain by bedrock at a depth probably in the range of 100 to 200 feet below sea level (Meng and Harsh 1988). The unconsolidated Potomac Formation sediments above the bedrock form a probable unconfined aquifer. Ground water likely flows north and east towards the Chickahominy River. Depth to ground water is variable, on the basis of the variable topography.

On the basis of data in Meng and Harsh (1988), the sequence of aquifers and confining units underlying the Cold Harbor and Gaines' Mill units, with approximate depths below land surface, are as follows: from land surface to 210 feet, surficial (unconfined) aquifer; 210 to 230 feet, Middle Potomac confining unit; 230 to 320 feet, Middle Potomac aquifer; 320 to 350 feet, Lower Potomac confining unit; 350 to 650 feet, Lower Potomac aquifer; and at 650 feet, basement rock.

The Drewry's Bluff unit is underlain by approximately 150 feet of unconsolidated sediment, which likely is an unconfined aquifer. In the higher elevations of the unit, from land surface, the first 10 feet consists of a shallow capping unit, probably Pleistocene-age sand and gravel (Inners *et al.* 1995). Underlying this capping unit is a thicker sequence of the Potomac Formation, which extends to the top of basement rock (Meng and Harsh 1988). Basement rock (probably the Petersburg Granite, Inners *et al.* 1995) is at a depth of approximately 55 feet below sea level (Meng and Harsh 1988). On the basis of the variable topography, depth to ground water at this site is highly variable. In general, the water table is deepest beneath the higher elevations along the river and shallower along the western edge of the unit and in the deep erosive cuts. Ground water movement is likely eastward towards the James River.

The Fort Harrison unit is underlain by basement rock at a depth of approximately 75 to 125 feet below mean sea level. The Lower Potomac Aquifer is partially present but probably does not attain its full thickness; it is unknown whether or not it is fully confined. The Lower Potomac confining unit may be partially present and is probably less than 20 feet thick (Meng and Harsh 1988). The Middle Potomac Aquifer is likely discontinuous and not of its full thickness; the altitude of the top of this aquifer is approximately 35 to 55 feet above mean sea level (Meng and Harsh 1988). The thickness of the Middle Potomac confining unit is approximately 20 feet (Meng and Harsh 1988). Sediments comprising the Aquia Aquifer, the Nanjemoy-Marlboro clay confining unit, the Calvert confining unit, and the Yorktown-Eastover Aquifer are likely present in the

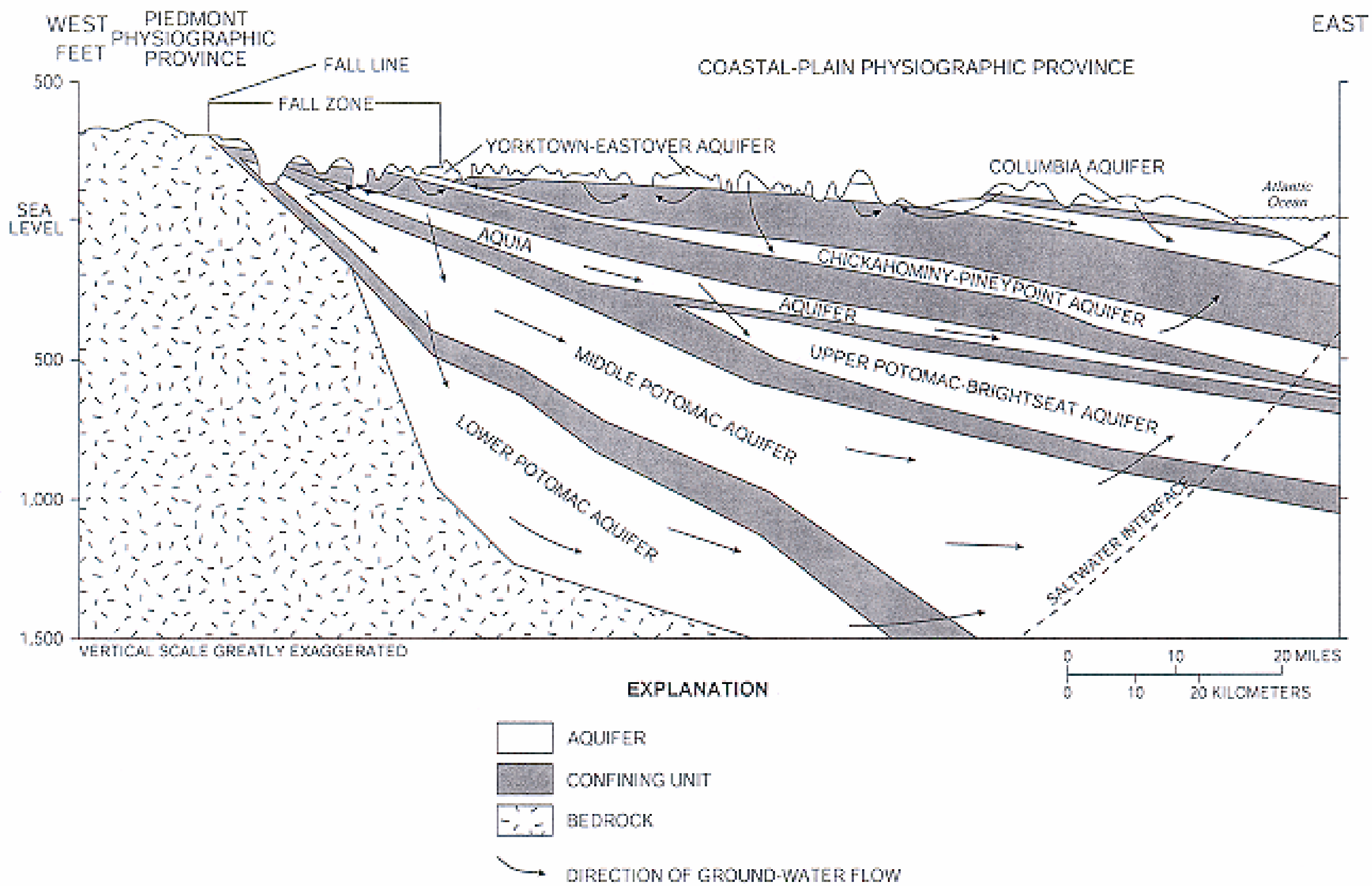

Figure 10. Generalized hydrogeologic section and direction of ground-water flow in the Coastal Plain Physiographic Province of Virginia. After MacFarland (1997).

subsurface over portions of the unit, but if present below the local ground-water table, they may not occur in the distinct and orderly sequence in which they occur farther to the east. The condition of these formations, with respect to whether they occur as confined, semi-confined, or unconfined aquifers, is unknown. Two wells, however, are reportedly screened in the Yorktown-Eastover and the Aquia aquifers (White *et al.* 2001); see section on Ground-Water Resources of the Fort Harrison unit.

The Malvern Hill and Glendale units are underlain by basement rock at a depth of approximately 250 to 400 feet below mean sea level. The altitude of the top of the Lower Potomac Aquifer is approximately 200 to 300 feet below mean sea level (Meng and Harsh 1988). The thickness of both the Lower Potomac and the Middle Potomac confining units is approximately 15 to 20 feet (Meng and Harsh 1988). The altitude of the top of the Middle Potomac Aquifer is approximately 50 to 90 feet below mean sea level (Meng and Harsh 1988). The altitude of the top of the Aquia Aquifer, which may be confined, partially confined, or unconfined across the unit, is approximately 10 to 40 feet below mean sea level (Meng and Harsh 1988). The thickness of the Nanjemoy-Marlboro clay confining unit is approximately 20 feet (Meng and Harsh 1988). Sediments comprising the Chickahominy-Piney Point Aquifer, the Calvert confining unit, and the Yorktown-Eastover Aquifer may be present in the subsurface over portions of the unit, but if present below the local ground-water table, they may not occur in the distinct and orderly sequence in which they occur farther to the east. The condition of these formations, with respect to whether they occur as confined, semi-confined, or unconfined aquifers, is unknown.

TOPOGRAPHY AND SOILS

Topography of the Coastal Plain Physiographic Province in general is characterized by large, relatively level terraces or plateaus. These upland areas are bounded by steep embankments that form the margins of waterways. Waterways are typically edged by swamps and other wetlands over much of their floodplains.

Topography in most of the park units is gently rolling and locally incised by streams; the exceptions are at Chickahominy Bluff and Drewry's Bluff, which have steep bluffs, and Malvern Hill, which has moderately steep slopes. Of the units addressed in this report, the minimum elevation is less than 10 feet (at the James River) in the Drewry's Bluff unit, and the maximum elevation is 185 feet in the Cold Harbor unit. The range in elevation for each unit shows that the Beaver Dam Creek unit has the flattest topography (Table 2).

Hodges (1978) mapped soils in Chesterfield County. In general, soils in the Drewry's Bluff unit are on uplands and are of the Gritney-Atlee-Lenoir association, which is characterized as deep, well drained to somewhat poorly drained soils, having a clayey or loamy subsoil. Specific details on the soils underlying each unit are shown in Table 2.

Table 2. Topography and soils of park units.

Unit	Range in Land Surface Elevation (ft.)	Soils
Beaver Dam Creek	85 – 100	Fluvaquents; Udults-Ochrepts complex
Chickahominy Bluff	85 – 175	Ochrepts and Udults; Norfolk fine sandy loam; Kempsville very fine sandy loam; Myatt fine sandy loam; Chewacla and Riverview
Cold Harbor	125 – 185	Caroline-Dogue complex; Kempsville gravelly fine sandy loam; Kenansville loamy sand; Orangeburg fine sandy loam; Suffolk loamy fine sand; Udults-Ochrepts complex
Drewry's Bluff	<10 – 100	Ochrepts and Udults; Faceville fine sandy loam; Dunbar fine sandy loam; Tetotum loam; Masada loam; Gritney fine sandy loam
Fort Harrison	80 – 140	Ochrepts and Udults; Ruston fine sandy loam; Atlee very fine sandy loam; Lenoir silt loam; Altavista fine sandy loam; Turbeville fine sandy loam and gravelly fine sandy loam; Pamunkey fine sandy loam; Roanoke silt loam; Rains very fine sandy loam; Bourne fine sandy loam; Angie loam; State fine sandy loam
Gaines' Mill	85 – 160	Caroline-Dogue complex; Kempsville-Bourne fine sandy loam; Suffolk loamy fine sand; Udults-Ochrepts complex
Malvern Hill and Glendale	47 - 145	Angie loam; Caroline very fine sand loam and clay loam; Chastain silt loam; Coxville silt loam; Kempsville fine and very fine sandy loams; Kinston and Mantachie soils; Lenoir silt loam; Lynchburg fine sandy loam; Mantachie-Chastain complex; Norfolk fine sandy loam; Ochrepts and Udults; Roanoke silt loam; Ruston fine sandy loam; Sassafras fine sandy loam; State fine sandy loam

Hodges *et al.* (1980) mapped soils in Hanover County. The soils underlying the Beaver Dam Creek, Cold Harbor, and Gaines' Mill units are classified as Coastal Plain soils, and include the Udults-Ochrepts-Suffolk association, the Ochrepts-Udults-Kempsville association, the Norfolk-Caroline-Dogue association, and the Norfolk-Orangeburg-Faceville association. These four soil associations are in general deep, moderately well to well drained and have a subsoil that is dominantly sandy, loamy, or clayey. These soils generally are found on uplands.

Clay (1975) mapped soils in Henrico County. The soils underlying the Chickahominy Bluff, Fort Harrison, Malvern Hill, and Glendale units are of the Kempsville-Atlee-Duplin association, the Ochrepts and Udults-Norfolk-Caroline association, or the Angie-Pamunkey-Lenoir association. These three soil associations are in general deep and well drained, some with gravel, some with a fragipan, and some poorly drained. These soils generally are found on uplands and stream terraces.

VEGETATION

Vegetation in this region of Virginia in general consists of second- and third-growth deciduous hardwood and coniferous forests, with oaks dominant, but also includes yellow poplar, sweetgum, blackgum, hickory, and maple. Evergreen trees include American holly, Virginia pine, and loblolly pine. Upland areas, if not developed, tend to be either in agricultural use or wooded. Stream bottoms can be swampy and are usually wooded. Specific information about the vegetation in each unit follows.

Beaver Dam Creek

The Beaver Dam Creek unit consists primarily of a wide wetland area bordering the creek, although a small percentage of the surrounding floodplain is forested and there is a section of mowed turf grass between the parking area and creek. Dominant trees in the forested floodplain include red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), and sycamore (*Platanus occidentalis*). Dominant understory species in this area include poison ivy (*Toxicodendron radicans*), greenbriar (*Smilax spp.*), and such exotic species as Chinese privet (*Ligustrum sinense*), Mimosa (*Albizzia julibrissin*), and Japanese honeysuckle (*Lonicera japonica*). The wetland area is not forested for the most part, however, it does contain a number of large snags. Dominant species in this area include several species of sedges (*Carex spp*.) and rushes (*Juncus spp*.), arrow arum (*Peltandra virginica*), pickerel weed (*Pontederia cordata*), cut grass (*Leersia spp*.), and the invasive exotic species Aneilema (*Murdannia keisak*) (Hayden *et al.* 1989).

Chickahominy Bluff

With the exception of the mowed areas surrounding the entrance road and interpretive overlook, the Chickahominy Bluff unit is primarily composed of forest. It is a combination of approximately 50% mixed hardwood and 22% mixed hardwood-conifer cover types (Helm and Johnson 1994). Both forest types exist in the bottomland areas on the north and east sections of the unit, and in the upland sections adjacent to the parking area. There are also sections of forest dominated by mixed oak species. These are found mostly in the areas adjacent to the small creek on the southeast boundary. Dominant species in the mixed hardwood forest type are sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*). In general, shrubs and vines make up the majority of understory vegetation, such as American holly (*Ilex opaca*) in the upland sections and sweet bay (*Magnolia virginia*) and sweet pepperbush (*Clethra alnifolia*) in the bottomland sections. The bottomland sections of this forest type have the largest herbaceous layer, including lizard's tail (*Saururus cernuus*) and sensitive fern (*Onoclea sensibilis*). Dominant species in the mixed hardwood-conifer forest type are sweetgum, loblolly pine (*Pinus taeda*), tulip poplar (*Liriodendron tulipifera*), and red maple. The understory is made up primarily of mixed hardwood saplings and the sparse herbaceous layer is made up primarily of vines. The stream area includes typical hydrophytic species such as arrowhead (*Sagittaria latifolia*), bugle weed (*Lycopus virginicus*), barnyard grass (*Echinochloa crus-galli*), cut grass (*Leersia oryzoides*), dayflower (*Commelina communis*), wild bean (*Apios americana*), and panic grass (*Panicum dichotomiflorum*) (Hayden and Johnson 1986). Invasive exotic species, such as tree of heaven (*Ailanthus altissima*) and Japanese honeysuckle (*Lonicera japonica*) are found only in roadside areas, such as adjacent to the entrance road and access road bisecting the unit. However, the invasive exotic species Aneilema (*Murdannia keisak*) is found in sections of the creek.

Cold Harbor

The Cold Harbor unit is forested on approximately 90% of its acreage, with the other 10% as a 13-acre hay field. Although the drier upland areas of the unit were previously dominated by pine, they are now covered by a mix of pine, oak, and oak-pine communities (Helm and Johnson 1994). A mixed hardwood community exists in the bottomlands along Bloody Run Creek and contains some of the unit's oldest and largest trees. Its canopy is dominated by blackgum (*Nyssa sylvatica*) and American holly (*Ilex opaca*), while sweet pepperbush (*Clethra alnifolia*), wild azalea (*Azalea viscosa*), and blueberry (*Vaccinium crymboxum* and *formosum*) dominate its very dense shrub layer. Its dense and relatively diverse herbaceous layer is dominated by skunk cabbage (*Symplocarpus foetidus*) and Jack-in-the-pulpit (*Arisaema triphyllum*). Other plants along Bloody Run Creek include swamp azalea (*Rhododendron viscosum*), sweet bay (*Magnolia virginiana*), cat brier (*Smilax laurifolia*), withe rod (*Viburnum cassinoides*), water starwort (*Callitriche heterophylla*), turtlehead (*Chelone glabra*), golden club (*Orontium aquaticum*), and yellow water lily (*Nuphar luteum*) (Hayden and Johnson 1986). This community has also been found to contain the rare Collins' sedge (*Carex collinsii*) (Ludwig and Pague 1993). The remaining communities are dominated by loblolly pine (*Pinus taeda*) and black oak (*Quercus velutina*) in the two pine community types, and white oak (*Quercus alba*), northern red oak (*Quercus falcata*), and American holly in the oak community type. The shrub layers in these communities consist primarily of saplings of species that dominate the canopy, along with hickory (*Carya tomentosa* and *glabra*), sassafras (*Sassafras albidium*), and blueberry (*Vaccinium formosum* and *stamineum*). Muscadine (*Vitus rotundifolia*), Virginia creeper (*Parthenocissus quinquefolia*) and Japanese honeysuckle (Lonicera japonica) dominate the relatively sparse herbaceous layer. Large portions of the Cold Harbor unit are mechanically maintained as open woodland parkland containing scattered oaks and loblolly pines. The Garthright House is surrounded by lawn grasses and ornamental shrubs, along with exotic plant species (National Park Service 1994).

Drewry's Bluff

The Drewry's Bluff unit is forested on approximately 60% of its acreage. Non-forested areas consist of a small mowed area at the unit's entrance, and a 5-acre meadow area overlaying an old county landfill. The fort itself is regularly cleared of all understory and herbaceous vegetation, leaving only sparse trees dominated by mixed hardwoods. The remaining forest is dominated by oak and oak-mixed hardwood cover types, with the latter found on steep slopes adjacent to the James River and No Name Creek, which cuts across the unit. Both types are dominated by sweetgum (*Liquidambar styraciflua*) and white (*Quercus alba*), red (*Quercus falcata*), and black (*Quercus velutina*) oaks in all forest strata. However, strawberry bush (*Euonymus americana*) and muscadine (*Vitus rotundifolia*) also are prevalent in the herbaceous layer. Exotic species, such as tree of heaven (*Ailanthus altissima*), Chinese privet (*Ligustrum sinense*), and Japanese stilt grass (*Microstegium vimineum*) are found in abundance along the steep slope leading from the landfill area down to the creek. Below the fort, on the bluff slope above the James River, a discontinuous ground-water seepage area supports mosses and liverworts, including the large liverwort *Marchantia polymorpha* (National Park Service 1994). Vegetation over the landfill consists mostly of a sparse cover of broom sedge (*Andropogon virginicus*), with scattered clumps of bush clover (*Lespedeza cuneata*), blackberry (*Rubus occidentalis*), and goldenrod (*Solidago spp*.), and scattered plants of mountain mint (*Pycnanthemum tenuifolium*), and panic grass (*Panicum spp*.) (Hayden and Johnson 1986). The stream valley, which drains the petroleum tank farm and the landfill, contains yellowroot (*Zanthorhiza simplicissima*), wood nettle (*Laportea canadensis*), toothwort (*Dentaria concatenata*), stonecrop (*Sedum ternatum*), wild chervil (*Chaerophyllum procumbens* and *Chaerophyllum tainturieri*), anise root (*Osmorhiza longistylis*), and spring beauty (*Claytonia virginica*) (Hayden and Johnson 1986).

Gaines' Mill

The Gaines' Mill unit consists of an open upland plateau covering approximately 40-50% of its acreage and consisting of mowed field, managed meadow, agriculture, and an early successional mixed hardwood-pine forest community. The remaining acreage consists of wooded slopes dominated by an oak forest community, with a wide bottomland community along Boatswain Creek. The mixed hardwood-pine community contains a canopy of sweetgum (*Liquidambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), and loblolly pine (*Pinus taeda*). The shrub and herbaceous layers consist of such early successional species as Virginia creeper (*Parthenocissus quiquefolia*), poison ivy (*Toxicodendron radicans*), and muscadine (*Vitus rotundifolia*). The older oak community is fairly open and park-like and is dominated by white oak (*Quercus alba*), American beech (*Fagus grandifolia*), and American holly *(Ilex opaca*). Some of the large beech trees likely were present during the Battle of Gaines' Mill in 1862. The shrub layer is dominated by American holly, blueberry (*Vaccinium formosum* and *pallidum*), and dangleberry (*Gaylussacia frondosa*). The herbaceous layer is sparse but relatively diverse and is dominated by muscadine and Japanese honeysuckle (*Lonicera japonica*) (Helm and Johnson 1994). Much of the forest near the cultivated fields is highly overgrown with Japanese honeysuckle, which has effectively eliminated much of the natural vegetation at ground level (Hayden and Johnson 1986). There is a large specimen of slippery elm (*Ulmus rubra*) along Boatswain Creek. Bittersweet (*Celastrus orbiculatus*) is present along the edges of the trail at both of its ends (Hayden and Johnson 1986).

Fort Harrison

The Fort Harrison unit is composed almost entirely of forest. Exceptions include the mowed areas surrounding the Visitor Center, Picnic Area, and Forts Harrison and Hoke, and Forts Brady and Gilmer are regularly cleared of all understory and herbaceous vegetation, leaving only sparse trees dominated by oaks and pines. Throughout the remaining areas, the dominant forest types are oak, oak-conifer, and mixed hardwood-conifer. Mixed hardwood and oak-mixed hardwood cover types surround the small wetland south of the maintenance access road (Maintenance Way) and north of Battlefield Park Drive (Helm and Johnson 1994). The dominant oak species in all of the oak communities listed above are white oak (*Quercus alba*) and southern red oak (*Quercus falcata*). However, loblolly pine (*Pinus taeda*) shares dominance in the oak-conifer cover type, and tulip poplar (*Liriodendron tulipifera*) shares dominance in the oak-mixed hardwood cover type. Mixed hardwoods and oak saplings dominate the understory of the oak-conifer cover type, with shrubs, such as wild azalea (*Azalea spp*.) and huckleberry (*Gaylussacia frondosa*), dominating the sparse herbaceous layer. Mixed hardwood saplings, such as blackgum (*Nyssa sylvatica*) and sweetgum (*Liquidambar styraciflua*), dominate the understory of the oak cover type, with shrubs again dominating the sparse herbaceous layer. Shrubs such as sweet pepperbush (*Clethra alnifolia*) dominate the understory, with an herbaceous layer dominated by partridgeberry (*Mitchella repens*), the invasive exotic Japanese honeysuckle (*Lonicera japonica*), and muscadine (*Vitus rotundifolia*). The mixed hardwood-conifer cover type is dominated, in the canopy and understory, by loblolly pine, red maple and sweetgum. These species also dominate in the herbaceous layer along with sweet pepperbush (*Clethra alnifolia*) and Lecothoe (*Lecothoe racemosa*). The mixed hardwood cover type is dominated by tulip poplar in the canopy, sweet pepperbush, and sweetbay (*Magnolia virginiana*) in the understory, and sweet pepperbush and blueberry (*Vaccinium spp.*) in the herbaceous layer. In general the invasive exotic Japanese honeysuckle (*Lonicera japonica*) exists in this unit on road and streamsides, but is not found in the interior forest. The wooded swamp west of Fort Harrison and south of the staff residences is dominated by ericaceous plants such as fetter bush (*Leucothoe racemosa*), stagger bush (*Lyonia mariana*), swamp azalea (*Rhododendron viscosum*), high-bush blueberry (*Vaccinium corymbosum*), squaw huckleberry (*V. stamineum*), and early sweet blueberry (*V. tenellum* and *V. vacillans*) (Hayden and Johnson 1986).

Malvern Hill/Glendale

The vegetation at the Malvern Hill and Glendale units is reflected in their diverse landscapes, ranging from flat uplands to rich coves, drier side slopes, moist bottomlands, and wetlands (Helm and Johnson 1994). These units are approximately 75% forested, with the other 25% consisting of either agricultural fields or lawns. Of the forested areas, nearly 50% is of the mixed hardwood and mixed hardwood-conifer forest types found in the bottom and uplands (Helm and Johnson 1994). The mixed hardwood-conifer type is dominated by sweetgum (*Liquidambar styraciflua*) and loblolly pine (*Pinus taeda*), although in many cases, loblolly pine is giving way to hardwoods through the natural process of succession. The understory is composed primarily of sweetgum, holly (*Ilex opaca*), and black oak (*Quercus velutina*) saplings, and the sparse herbaceous layer consists of sweetgum, white oak (*Quercus alba*), and red maple (*Acer rubrum*) seedlings. Much of the cove, wetland, and other poorly drained areas are of the mixed hardwood forest type. This type is dominated by sweetgum, red maple, and tulip poplar (*Liriodendron tulipifera*) in the canopy, loblolly pine and black oak in the subcanopy, and sweetgum and loblolly pine in the sparse herbaceous layer. Other cover types include oak-conifer and oak-mixed hardwood. The oak-conifer types is found on the uplands and is dominated by loblolly pine and white oak in the canopy, mixed oaks, sweetgum, red maple, and American elm (*Ulmus americana*) in the subcanopy, and sweetgum and loblolly pine seedlings, grasses and sedges in the herbaceous layer. The oak-mixed hardwood cover type exists both in bottomlands and uplands and is dominated by mixed oaks in the canopy, spicebush (*Lindera benzoin*) in the subcanopy and tulip poplar seedlings in the herbaceous layer. There is a mature stand of bald cypress trees along the McDowell Creek stream corridor (OCULUS 2000). Invasive exotic species such as bull thistle (*Cirsium vulgare*), Canada thistle (*Cirsium arvense*), garlic mustard (*Alliaria petiola*), Japanese honeysuckle (*Lonicera japonica*), Japanese stilt grass (*Microstegium vimineum*), Johnson grass (*Sorghum halepense*), multiflora rose (*Rosa multiflora*), and tree of heaven (*Ailanthus altissima*) have been observed in these units (OCULUS 2000). Crops in the agricultural areas include soybeans, corn, and winter wheat (OCULUS 2000).

FLOODPLAINS, RIPARIAN AREAS, AND WETLANDS

Floodplains, riparian areas, and wetlands occur at the interface between land and water. Collectively these areas represent only a small proportion of the landscape in Richmond NBP, however, their hydrologic and ecological importance is significant (Naiman *et al.* 1993). Individually and collectively, these areas provide critical functions such as water supply, maintenance or improvement of water quality through physical and chemical processes, drainage ways for hydrologic systems, flood attenuation, essential habitats for flora and fauna, and maintenance of the biodiversity. In general, wetland soils are associated with most of the waterways in the park. Numerous areas of upland wetlands are situated between waterways where topography and internal drainage create locally moist conditions.

Natural riparian areas are some of the most diverse, dynamic, and complex biophysical habitats in the terrestrial environment (Naiman *et al.* 1993). The riparian area encompasses that part of the stream channel between low and high water marks and that portion of the terrestrial landscape from the high water mark toward the uplands where vegetation may be influenced by elevated water tables or flooding and by the ability of the soils to hold water (Naiman and Decamps 1997). Thus, riparian areas may be considered ecotones between the aquatic habitat of a river and the surrounding terrestrial habitats. The riparian zone is often small in headwater streams. In mid-sized streams, the riparian zone is larger, represented by a distinct band of vegetation whose width is determined by long-term (>50 years) channel dynamics and the annual discharge regime. Riparian zones of large streams are characterized by well-developed but physically complex floodplains with long periods of seasonal flooding, lateral channel migration, oxbow lakes in old river channels, a diverse vegetative community, and moist soils (Malanson 1993). These attributes suggest that riparian zones are key systems for regulating aquatic-terrestrial linkages (Ward 1989), and that they may be early indicators of environmental change (Decamps 1993).

AQUATIC BIOLOGICAL RESOURCES

Raney (1950) was the first to comprehensively assemble all known information on freshwater fishes in the James River. Since that time the only significant works include a comprehensive study of the Piedmont section of the James River (Woolcott 1974); fish community studies of the main stem James River (Garman *et al.* 1991); and a book on the freshwater fishes of Virginia (Jenkins and Burkhead 1993). Maurakis and Woolcott (1995) updated the work of Raney, providing the most current list of freshwater fishes in the James River basin.

The James River fish fauna is fairly species rich for an Atlantic slope drainage, with 108 freshwater species (59 genera) in 21 families of fishes (81 native and 27 introduced species) including three endemics (two species and one subspecies) (Maurakis and Woolcott 1995). The Piedmont portion of the James River contains 85 species, the mountainous portions (which include the Blue Ridge and Valley and Ridge Physiographic provinces), 67, and the Coastal Plain portion, 75. Fourteen species are limited to the Coastal Plain; seven species are limited to the mountainous region; and, two species are limited to the Piedmont. Twenty-five species are shared between the Piedmont and Coastal Plain Physiographic provinces.

The high number of native fish species in the James River comes mainly from southern Coastal Plain elements, Susquehanna drainage elements, upland and montane species in the Roanoke drainage or Ohio basin, and by mechanisms such as stream capture, including subterranean connections, extended rivers, and estuarine flooding (Jenkins and Burkhead 1993). In general it appears that the James River fish fauna as a whole is a composite, with species derived from elements in drainages both to the north and south (Maurakis and Woolcott 1995).

There are no known studies of the fish fauna of any drainage within Richmond NBP except for Boatswain and Beaver Dam creeks. In 1995 the Virginia Department of Game and Inland Fisheries collected fish from Boatswain Creek in May (one site) and from Beaver Dam Creek at two different sites in May and October (Robert Greenlee, Virginia Department of Game and Inland Fisheries, pers. comm. 2002). Boatswain Creek yielded only three species – creek chub (*Semotilus atromaculatus*) was the predominate species (88% by number). The low number of species is not unexpected; generally, only a relatively few fish species in a drainage occupy a given stream site or reach. Based on Jenkins and Burkhead's (1993) sampling, small creeks in this setting typically have 2 to

10 fish species. Given the presumed flow characteristics of several small park drainages (such as Bloody Run), when fish species are present, the number of species is probably similar to that of Boatswain Creek.

Beaver Dam Creek, on the other hand, yielded 14 fish species (163 total individuals) in May and 10 (30 total individuals) in October. At the site sampled in the spring, bluespotted sunfish (*Enneacanthus gloriosus*) was the dominant fish (42%); however, five species, bluespotted sunfish, creek chubsucker (*Erimyzon oblongus*), brown bullhead (*Ictalurus nebulosus*), tadpole madtom (*Noturus gyrinus*), and golden *shiner (Notemigonus crysoleucas*), comprised 80% of the catch by numbers. At the site sampled in the fall, two species—largemouth bass (*Micropterus salmoides*) and chain pickerel (*Esox niger*)—comprised almost 50% of the catch by number.

In 2002, the National Park Service completed a fisheries survey of Beaver Dam Creek, Boatswain Creek, Bloody Run, Western Run, and Crewes Channel. A report on this survey is forthcoming and therefore the results are unavailable at this time.

A local study of the effects of urbanization on stream fish assemblages by Weaver and Garman (1994) was conducted in the watershed of Tuckahoe Creek, the last major tributary to the James River above the Fall Line and only 12 miles west of Richmond. Land use in the Tuckahoe Creek watershed has been shifting from rural to suburban over the last three decades. In the late 1950s the watershed was dominated by forest and crops, and had a population density of one person per 2 acres. Over the next 30 years the population in the watershed tripled, the number of road crossings doubled, the road length in the basin more than doubled, the number of dwellings and riparian zone development quadrupled, and impervious cover in the watershed more than doubled. Not surprisingly, Weaver and Garman (1994) found that the fish community of Tuckahoe Creek had changed significantly over the same timeframe. Only 412 fish were collected in their 1990 survey compared to 2,056 in a 1958 study, despite equal sampling efforts. Thirty-two species were collected in 1958, whereas only 23 species were collected in 1990 (six species collected in 1958 were absent in 1990). In 1990 two species represented 67 percent of the catch – both species were habitat and trophic generalists, allowing them to respond to changing stream conditions over time. On the other hand, populations of two other historically dominant species declined by more than 55 percent. Species that use the stream substrate either as habitat and/or for reproduction were probably affected by increased sediment deposition and siltation that occurred as a result of urbanization. This study is important to the park for two reasons: (1) it shows how it is imperative to establish biological baseline conditions for the park's water resources now, before additional urbanization can occur; and (2) it confirms the use of biological monitoring as a valuable tool – biological indicators respond to and integrate all the various factors that affect a stream. The findings from Tuckahoe Creek over a three-decade period of development are consistent with the body of stream ecological research, which shows that even a small degree of watershed development can produce dramatic change in the biodiversity of streams.

There are no known studies of the aquatic flora and macroinvertebrates of streams or wetlands within Richmond NBP. However, the macroinvertebrate community of the tidal section of the James River is dominated by two taxonomic groups (Sickel 1980; Jensen 1974)– oligochaete worms and chironomid larvae – resulting in a community very different from that above Richmond in the Piedmont [75 species vs. 196 genera in the Piedmont (Woolcott 1974)]. This lower taxonomic richness in the tidal section of the James River and the dominance of burrowing tubificids might be expected due to a shift in substrate composition to fine organic and inorganic particulates. Inputs of organic and chemical pollutants, now largely abated, may also have reduced richness to levels typical of stressed environments.

To date, there has been no biological monitoring in or near any units of Richmond NBP by Virginia DEQ, and there are no plans to include sites in the park in the future (Richard Daub, Virginia DEQ, pers. comm. 2000). Some sites in Richmond NBP might be useful in the monitoring network as unimpaired or "reference" sites; however, no resources currently are available to expand the State's monitoring network (Richard Daub, Virginia DEQ, pers. comm. 2000).

DESCRIPTION OF WATER RESOURCES

All of the park units are within the 64,000 mi^2 Chesapeake Bay and the 10,102 mi^2 James River watersheds. The Drewry's Bluff, Fort Harrison, Glendale, and Malvern Hill units are drained by small streams into the main stem of the James River. The Beaver Dam Creek, Chickahominy Bluff, Cold Harbor, and Gaines' Mill units are drained by small streams into the main stem of the upper Chickahominy River, which drains to the James River and ultimately to the Chesapeake Bay.

The James River watershed is the largest watershed in Virginia, drains one-fourth of the state's land area, and contains nearly one-third (1.7 million) of Virginia's population. Average flow of the 340-mile-long James River is 4,884 millions gallons per day. The James River is the third largest tributary to the Chesapeake Bay. Industries in the James River watershed include transportation, chemicals, furniture, textiles, shipping, shipbuilding, and tourism. Numerous high-density residential and commercial properties within the basin create great demand for water from the James River. A land-use map of the Coastal Plain portion of the James River watershed clearly indicates the development pressures surrounding the city of Richmond, including the three counties in which the park units are situated (Figure 11 a,b). The two major tributaries to the tidal portion of the James River, which extends upstream to the Fall Line in Richmond, are the Appomattox River and the Chickahominy River. The Chickahominy River watershed (470-mi^2 watershed) is characterized by suburban areas in the upper one-third and predominantly forested areas mixed with residential areas and farmland in the lower two-thirds of the watershed. Timber harvesting in the Chickahominy River watershed is an important part of the local economy.

There are no stream-gaging stations within any of the park units, so no direct information about surface-water quantity is available. Two stream-gaging stations are

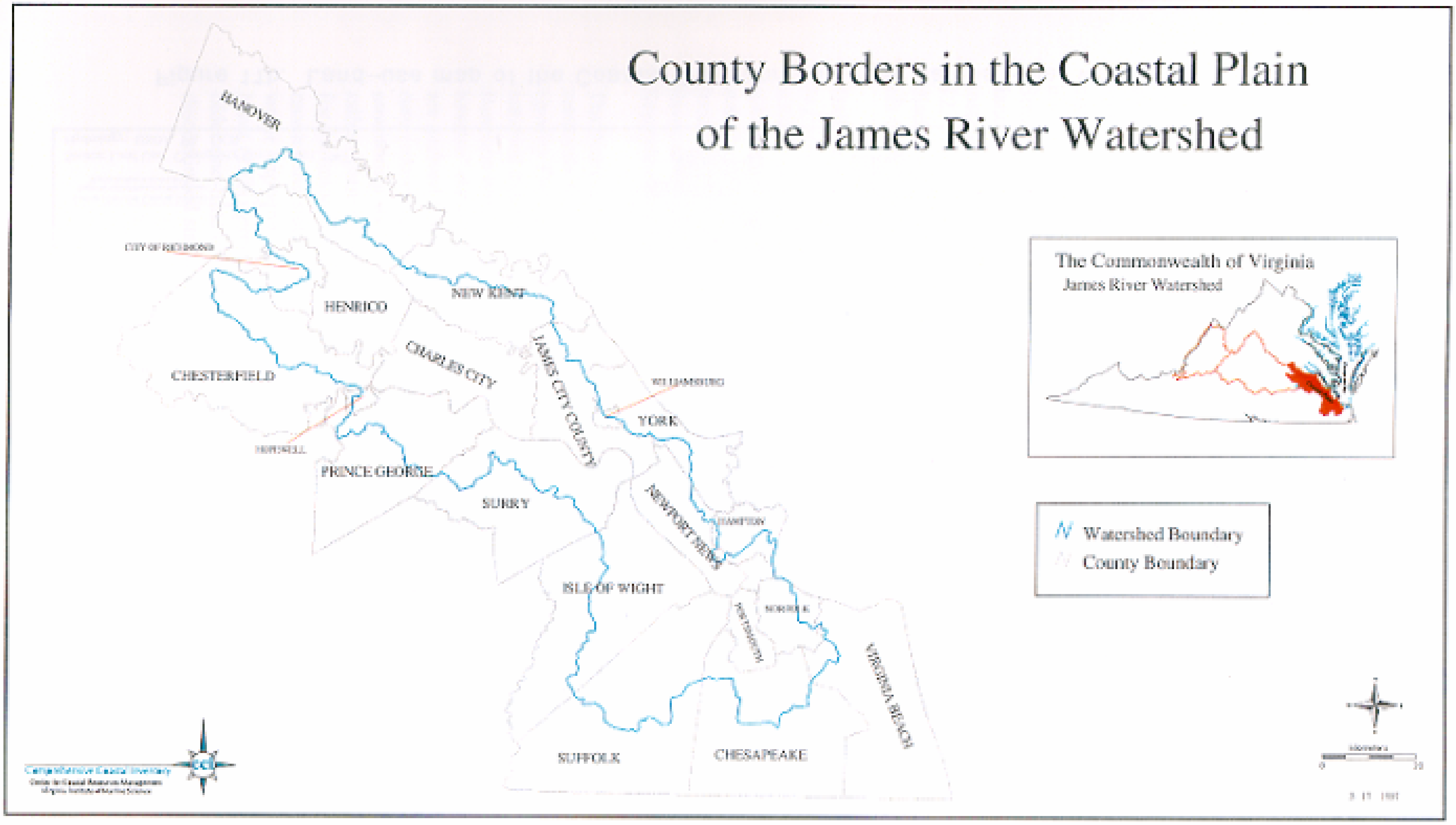

Figure 11a. County borders in the coastal Plain of the James River watershed.

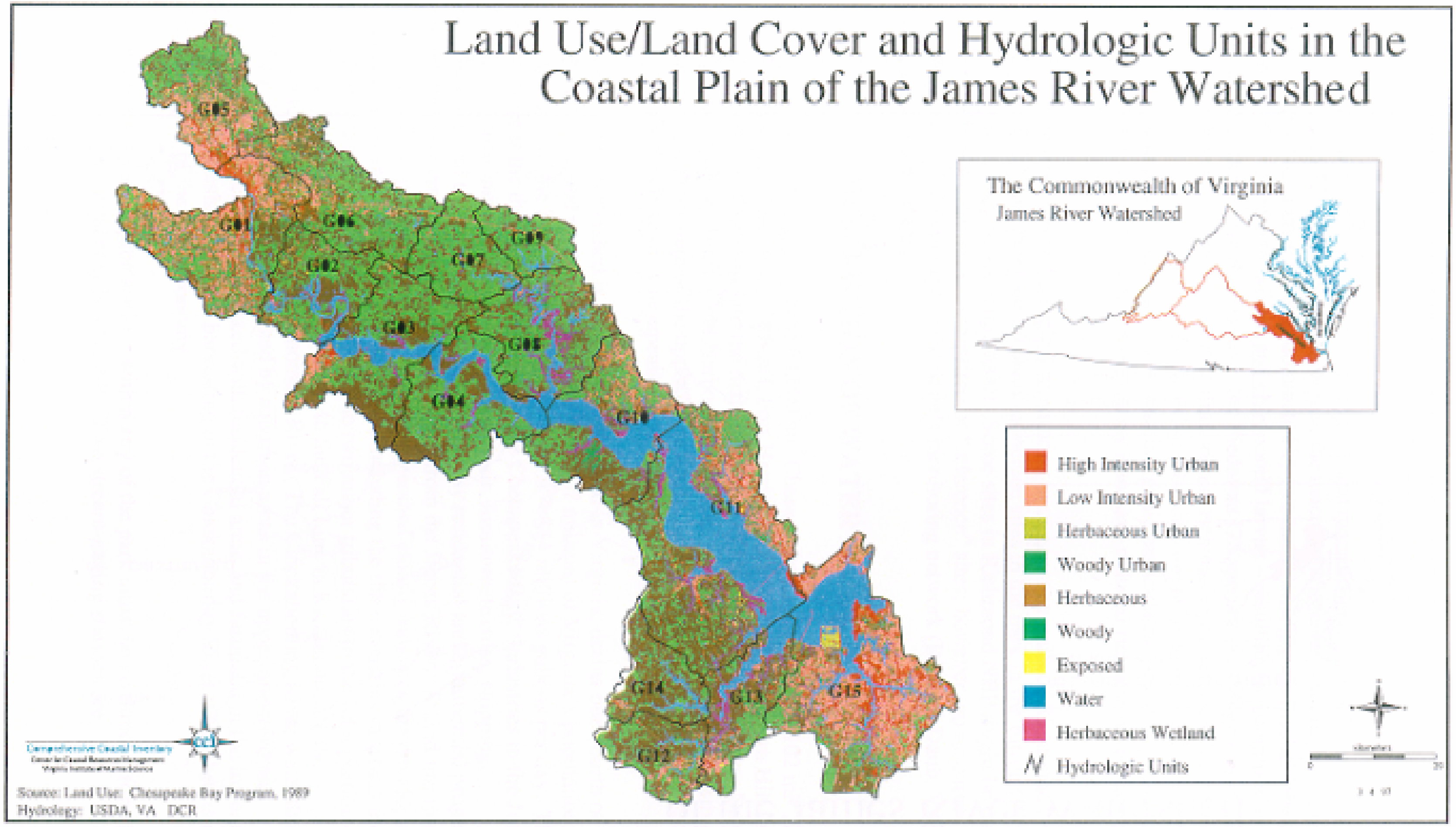

Figure 11b. Land-use map of the Coastal Plain portion of the James River watershed.

in the vicinity of Richmond NBP, one on the James River and one on the Chickahominy River (White *et al.* 2002). The gaging station on the James River (station 02037500) is in Henrico County near the city of Richmond and has a drainage area of 6,758 mi^2. The gaging station on the Chickahominy River (station 02042500) is in New Kent County near Providence Forge and has a drainage area of 252 square miles (mi^2). Stream discharge data have been collected at station 02037500 continuously since October 1934, and for the period of record, the maximum instantaneous discharge was 313,000 cubic feet per second (cfs) on June 23, 1972 (White *et al.* 2002). The minimum instantaneous discharge was not determined but probably occurred September 8-15, 1966 (White *et al.* 2002). During the 2001 water year (October 1, 2000 through September 30, 2001), maximum instantaneous discharge was 40,700 cfs on March 31, 2001 and minimum instantaneous discharge was 721 cfs on September 13 and 24, 2001 (White *et al.* 2002). Stream discharge data have been collected at station 02042500 continuously since January 1942, and for the period of record, the maximum and minimum, respectively, instantaneous discharges were 7,710 cfs on August 15, 1955 and 0.06 cfs on September 12, 1997 (White *et al.* 2002). During the 2001 water year, maximum instantaneous discharge was 1,590 cfs on April 3, 2001 and minimum instantaneous discharge was 0.75 cfs on July 19, 2001 (White *et al.* 2002).

Daily mean discharge for the two stream-gaging stations for the 2001 water year is shown in Figure 12. Daily mean discharge of streams in the park units should follow a pattern similar to that shown in Figure 12, although the magnitude of discharge would be substantially less because the drainage areas are much smaller than that of these stations. Another USGS stream-gaging station (02042287) with a drainage area of 62.2 mi^2, located approximately 9 miles upstream of the Cold Harbor unit on the Chickahominy River near Atlee, Virginia, was operated from January 1990 through the end of September 1997 (White *et al.* 2002).

The National Park Service has developed a baseline survey of surface-water-quality data retrievals for Richmond NBP (National Park Service 1999). This Baseline Water-Quality Data Inventory and Analysis Report is a download of six of the U.S. EPA's national databases, including STORET. No interpretation of the water-quality data in the Baseline report is provided. Users of STORET are strongly advised that it is a "user-beware" database system, because there is no quality assurance of the data and the data are derived from and entered into the system by a wide variety of sources. The STORET data (retrieved 8/4/1999) in the Baseline report were reviewed for water-quality monitoring stations in and near each of the park units. The study area included data 3 miles upstream and 1 mile downstream of park boundaries. The results of these retrievals for Richmond NBP cover the years 1945 through 1998 and include 149 water-quality monitoring stations, 32 industrial/municipal dischargers, four drinking-water intakes, 23 water impoundments, and 14 active or inactive USGS (or other) stream-gaging stations. Most (132) of the monitoring stations are outside park boundaries. Most represent either older one-time or intensive single-year sampling efforts by collecting agencies or discontinued stations.

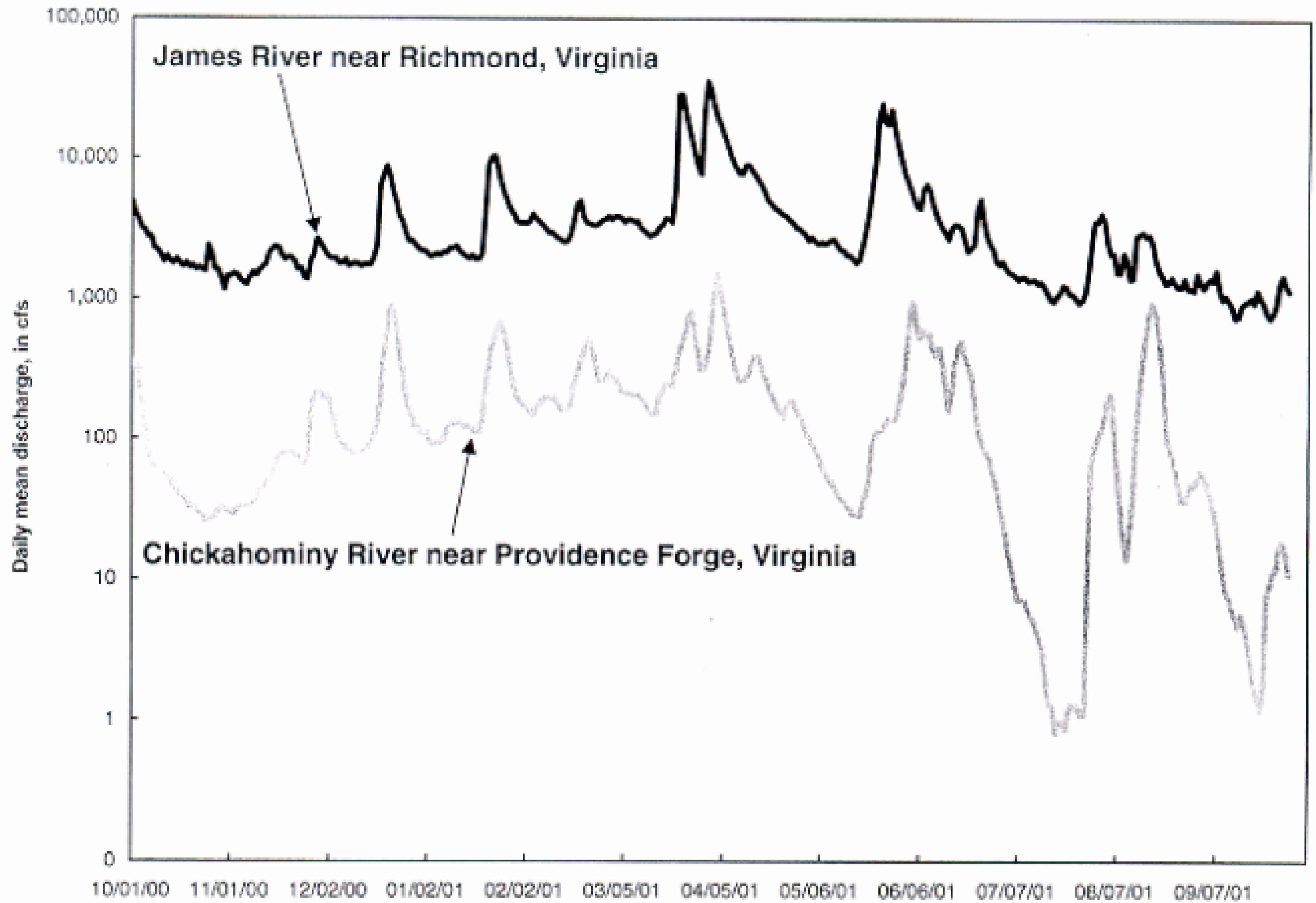

Figure 12. Daily mean discharge at the James River near Richmond (02037500) and the Chickahominy River near Providence Forge, Virginia (02042500) stream-gaging stations, October 1, 2000 - September 30, 2001.

Seventeen of the water-quality monitoring stations were located within the park boundaries. Sixteen of these 17 stations were located within the Drewry's Bluff unit and one station was within the Beaver Dam Creek unit. Forty-nine stations within the study area (one within park boundaries) yielded longer-term (i.e. multiple years) records consisting of multiple observations for several important water-quality parameters.

The station within park boundaries yielding the longer-term record is Beaver Dam Creek at the State Route 156 Bridge at Mechanicsville (RICH0136). This station exceeded the EPA water-quality criterion of a low limit pH standard four times out of six observations, and a drinking water standard for cadmium once out of four observations.

Fifteen of the 16 stations at the Drewry's Bluff unit were related to studies performed by Del Nimmo of the National Park Service in 1989, Draper Aden in 1996, or Texas A&M University in 1997. These studies are described in the section "Drewry's Bluff" under "Water Resources Planning Issues and Recommendations." The other station at Drewry's Bluff (RICH0050) has no qualifying data to identify the study; data were collected from 1976-78.

The stations with the longest-term records within the study area, but outside of park boundaries, are: 1) James River at the U.S. Route 360 Bridge; 2) Almond Creek at the State Route 5 Bridge; 3) Chickahominy River at the U.S. Route 360 Bridge; 4) Falling Creek at the U.S. Route 1 Bridge; 5) James River at Buoy 157; 6) Chickahominy River at the State Route 156 Bridge; and 7) James River at Buoy 166.

The data from the 17 park-based stations and the seven long-term stations show historical water quality conditions and may be useful, in a limited way, for displaying historical trends, but are of little use in an assessment of current water quality. An assessment of current water quality in the park was recently completed. A Level I Water Quality Inventory and Monitoring (WAQIM) assessment was conducted for Richmond NBP by the USGS, Water Resources Division, Virginia District. The WAQIM focused on the seven units that are included in this Water Resources Management Plan (i.e., Beaver Dam Creek, Chickahominy Bluff, Cold Harbor, Drewry's Bluff, Fort Harrison, Gaines' Mill, and Malvern Hill/Glendale). The WAQIM included quarterly collection of physical and surface water quality data from key water bodies (n=15) in each of the units. Sample collection occurred from August 2001 through April 2002. A total of 64 water-quality samples was collected, including four quality assurance/quality control samples to insure data quality. These data can serve as a baseline of water quality for the park, against which future changes in water quality, improvement or degradation, can be measured. The entire Level I WAQIM for Richmond NBP is contained in Appendix C.

Additionally, the USGS water-quality database QWDATA was checked for all surface- and ground-water quality data collected in Chesterfield, Hanover, and Henrico counties, and data pertinent to each park unit are discussed in the following sections.

The general hydrogeology of the Coastal Plain Physiographic Province was discussed above (see section entitled "Hydrogeology"). Human activities can affect the quality of ground water and include the following: application of pesticides and fertilizer to cultivated land, disposal of human wastes in septic tanks, cesspools, or wastewater treatment plants, and storage of petroleum or other liquids in leaky underground tanks. Specific information about ground water quantity and quality is discussed below for each unit of the park.

The U.S. Fish and Wildlife Service classifies wetlands for the National Wetlands Inventory (NWI) according to the document "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin *et al.* 1979). Wetlands were assessed for this plan using 1:24,000-scale NWI maps (U.S. Fish and Wildlife Service 1993), in conjunction with a publication entitled "Form and Function of Forested Wetlands: Richmond National Battlefield Park" (Johnson *et al.* 1994).

NWI maps are useful for a general understanding of the potential areal extent and types of wetlands that are present. These maps, however, are often many years old, not ground-truthed, and the scale (1:24,000) is not sufficiently large to detect subtle changes that may be occurring with respect to habitat boundaries or species composition changes, or to delineate small wetland sources, such as seeps or springs. Because of their limited accuracy and precision, NWI maps are only a first step in a wetland inventory for the park. A parkwide wetland delineation is in progress by the USGS, National Wetland Research Center, however, associated data were not available in time for use on this plan. The purpose of the wetlands study is to ground truth the NWI map, determine its accuracy, and identify any wetland areas not mapped.

A wetland inventory was conducted during 1992 by Virginia Tech to determine the extent of jurisdictional wetlands within the park boundaries (Johnson *et al.* 1994). The researchers used the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (Federal Interagency Committee for Wetland Delineation 1989). Potential wetlands were identified by use of aerial photography. Within each potential wetland, a grid system was established and from 10 to 36 sample points were created. At each sample point, data were collected concerning vegetation, soils, and hydrology. Wetland boundaries were then drawn between points with differing wetland data, and the jurisdictional determination was made. The Johnson *et al.* (1994) publication includes maps and descriptions of park wetlands created on the basis of the field sampling data.

On the basis of the two documents describing wetlands in Richmond NBP, the majority of the wetlands in the park are classified as palustrine wetlands. Palustrine wetlands are non-tidal and dominated by trees, shrubs, persistent emergent vegetation and emergent mosses or lichens (Cowardin *et al.* 1979). This broad classification was developed to group the vegetated wetlands traditionally called by such names as marsh, swamp, bog, fen, and prairie. It also includes the small, shallow, permanent, or intermittent water bodies often called ponds. Palustrine wetlands may be situated shoreward of lakes or river channels; in isolated catchments on river floodplains; or on slopes. They may also occur as islands in lakes or rivers. The erosive forces of wind and water are of minor importance to palustrine wetlands, except during severe floods.

BEAVER DAM CREEK

Watershed Description

The Beaver Dam Creek unit consists almost entirely of a 0.2-mile length of Beaver Dam Creek and its associated wetlands. The creek begins approximately 4 miles northeast of the unit, is joined by Brandy Branch Creek very close to its entrance into the park, and flows approximately 0.5 mile southeast into the Chickahominy River (Figure 13). This watershed exists immediately south of the intersection of Mechanicsville Turnpike and I-295, both of which cross Beaver Dam Creek. Although this creek appears to have a forested buffer along most of its length, the buffer is surrounded by residential and commercial development within the Richmond suburb of Mechanicsville.

Surface-Water Resources

As discussed above, the main surface-water body in the unit is Beaver Dam Creek, a small tributary of the Chickahominy River. North of the unit, Beaver Dam Creek flows through highly suburbanized Mechanicsville, beneath an I-295 interchange, is joined by Brandy Branch, then flows beneath Rt. 156 and through the park unit to discharge to the Chickahominy River.

There are no stream-gaging stations within the Beaver Dam Creek unit, so no direct information about surface-water quantity is available. The surface-water hydrograph will be similar in shape to that shown in Figure 12, as described above.

In 1987, the National Park Service performed water testing for the parasitic amoeba *Naegleria fowleri* within the unit, but none were found (documents on file at Richmond NBP).

In 1988 and 1989, the Virginia Department of Health sampled for biological oxygen demand (BOD), suspended solids, dissolved solids, and turbidity in Beaver Dam Creek. They found that the water had low BOD levels and had a turbidity ranging from 2.4 to 14.1 Formazin turbidity units (documents on file at Richmond NBP).

In 1996, temperature, pH, dissolved oxygen, specific conductance, redox potential, and hardness were determined (data sheets on file at Richmond NBP).

According to the USGS QWDATA database, Beaver Dam Creek at the Route 156 bridge at Mechanicsville (station ID 02042433) has been sampled from 1984-2002. The 2001-2002 Level I WAQIM study represents the best assessment of current water quality conditions in the Beaver Dam Creek unit. Sampling occurred quarterly from August 2001 to April 2002. See Appendix C for the results of this sampling. Table 3 summarizes water quality data collected from Beaver Dam Creek during the Level I WAQIM. No State water quality standards were exceeded except for pH, which was below the State standard of 6.0 pH units in three out of four samples. However, this stream and most of the streams in other units of the park drain low-gradient and/or

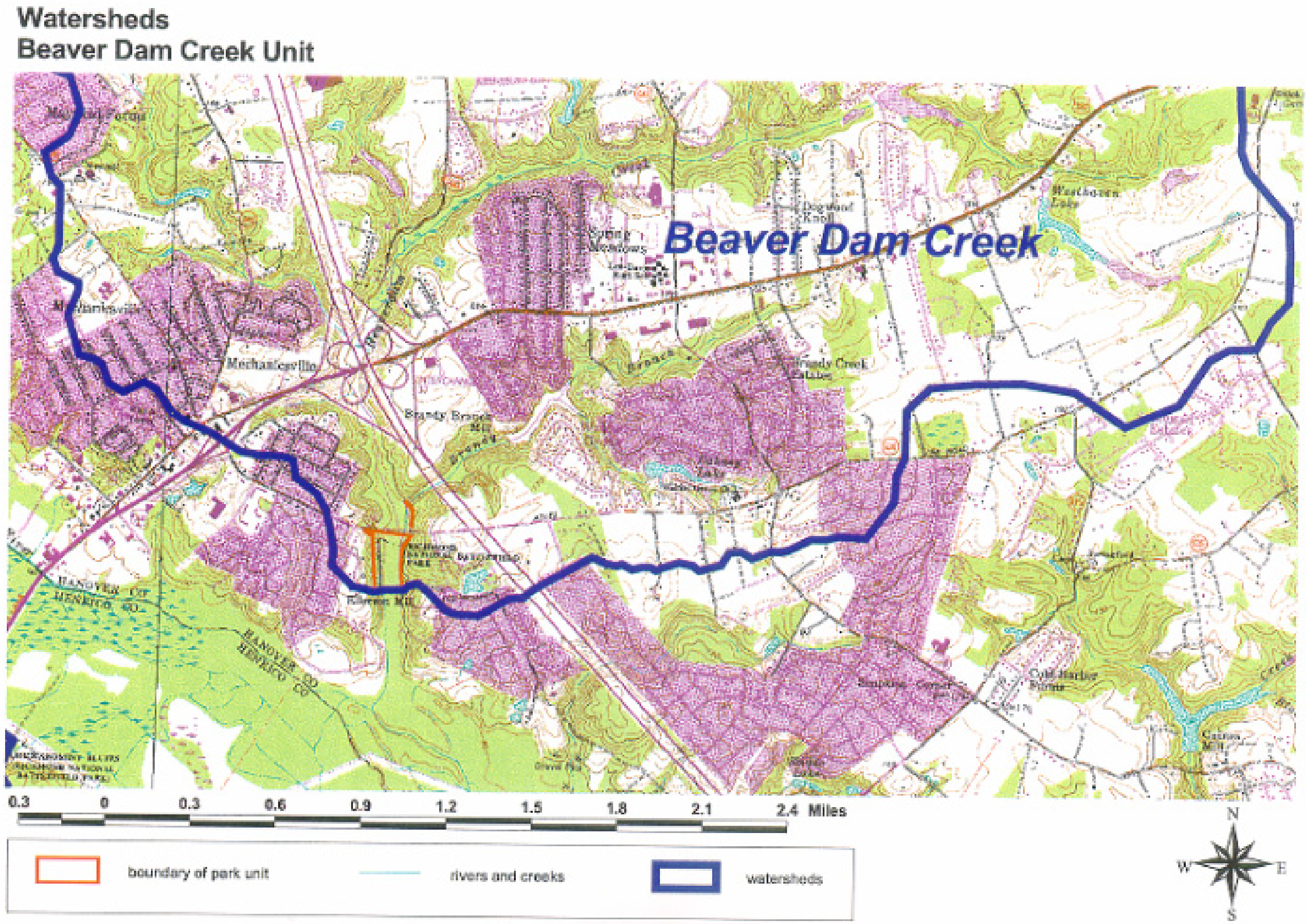

Figure 13. Map showing watershed contributing to the Beaver Dam Creek unit.

wetland areas that naturally contain high concentrations of organic acids, which would lower pH. Additionally, the low alkalinity values and low acid neutralizing capacity for Beaver Dam Creek are indicative of swampy areas and help to explain the lower pH. All other parameter values are unremarkable. This suite of water quality parameters does not indicate a strong influence from surrounding land use.

Ground-Water Resources

Ground-water resources are not in use at this unit. The area serves as a ground-water discharge zone to Beaver Dam Creek and associated wetlands.

Table 3. Results of surface-water samples collected from Beaver Dam Creek at the Route 156 bridge in the Beaver Dam Creek unit during the 2001-2002 Level I WAQIM. Not all water quality parameter results are shown. Refer to Appendix C for complete water quality parameter results and sample location.

Water-Quality Parameter, unit	Range, Sample Size
Discharge, ft^3/s	---
Dissolved oxygen, mg/L	5.5-10.3, n=4
Field pH, standard units	5.7 – 6.8, n=4
Specific conductance, µS/cm	101-124, n=5
Water temperature, ºC	8-23.7, n=4
Alkalinity, mg/L as $CaCO_3$	12 – 20, n=4
Dissolved calcium, mg/L	4.15, n=1
Dissolved magnesium, mg/L	2.8, n=1
Dissolved potassium, mg/L	2.75, n=1
Dissolved sodium, mg/L	8.5, n=1
Acid neutralizing capacity, mg/L as $CaCO_3$	20, n=1
Dissolved chloride, mg/L	13.3, n=1
Dissolved fluoride, mg/L	0.1, n=1
Dissolved silica, mg/L	4.9, n=1
Fecal coliform, col./100 mL	67-470, n=4
Dissolved ammonia, mg/L as NH_4	0.04 – 0.124, n=4
Dissolved nitrogen, mg/L as N	1-1.7, n=4
Total phosphorus, mg/L	<0.004 – 0.041, n=4
Aluminum, µg/L	50, n=1
Dissolved iron, µg/L	1060, n=1
Dissolved manganese, µg/L	35, n=1

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; n=, number of samples; °C, degrees Celsius; col., colonies; µS/cm, microsiemens per centimeter at 25 °C; $CaCO_3$, calcium carbonate; NH_4, ammonium; µg/L, micrograms per liter; --, no data]

Wetland and Riparian Resources

The Beaver Dam Creek unit consists of approximately six acres of palustrine wetland. It is predominantly composed of permanently flooded areas inhabited by persistent emergent plants. However, sporadic beaver activity downstream creates semi-permanently flooded areas dominated by broad-leaved deciduous shrubs. Palustrine wetlands are non-tidal and dominated by trees, shrubs, persistent emergent vegetation and emergent mosses or lichens (Cowardin *et al.* 1979).

Water Supply and Sewage Disposal

No such infrastructure exists at this unit.

CHICKAHOMINY BLUFF

Watershed Description

Chickahominy Bluff is situated on the uplands, steep slopes, and forested wetlands adjacent to the Chickahominy River floodplain. The southeastern corner is bisected by two small, unnamed streams, which begin approximately 0.25 mile southwest of the unit, join within the unit, and flow northeast into the Chickahominy River (Figure 14). This is the only perennial stream within the unit, however, the northern section of the unit (approximately one-third of the unit) consists of a forested wetland within the Chickahominy River floodplain. Because there are wetlands immediately north and east of the unit, and south of the Chickahominy River, this area has remained relatively undeveloped. Mechanicsville, however, a well-developed suburb of Richmond, lies southwest of both the river and the park unit. The Mechanicsville turnpike, a major thoroughfare, bounds the park to the west and crosses the Chickahominy River. The southern boundary of the unit, as well as the tributary headwaters, are surrounded by residential and industrial development, including a filtration plant.

Surface-Water Resources

As described above, the southeastern corner of the unit is bisected by two small tributaries, which join within the unit, and exit the unit to contribute to the Chickahominy River.

No stream-gaging stations exist within the Chickahominy Bluff unit, so no direct information about surface-water quantity is available. The surface-water hydrograph will be similar in shape to that shown in Figure 12, as described above.

In 1996, temperature, pH, dissolved oxygen, specific conductance, redox potential, and hardness were determined (data sheets on file at Richmond NBP).

Watersheds
Chickahominy Bluff Unit

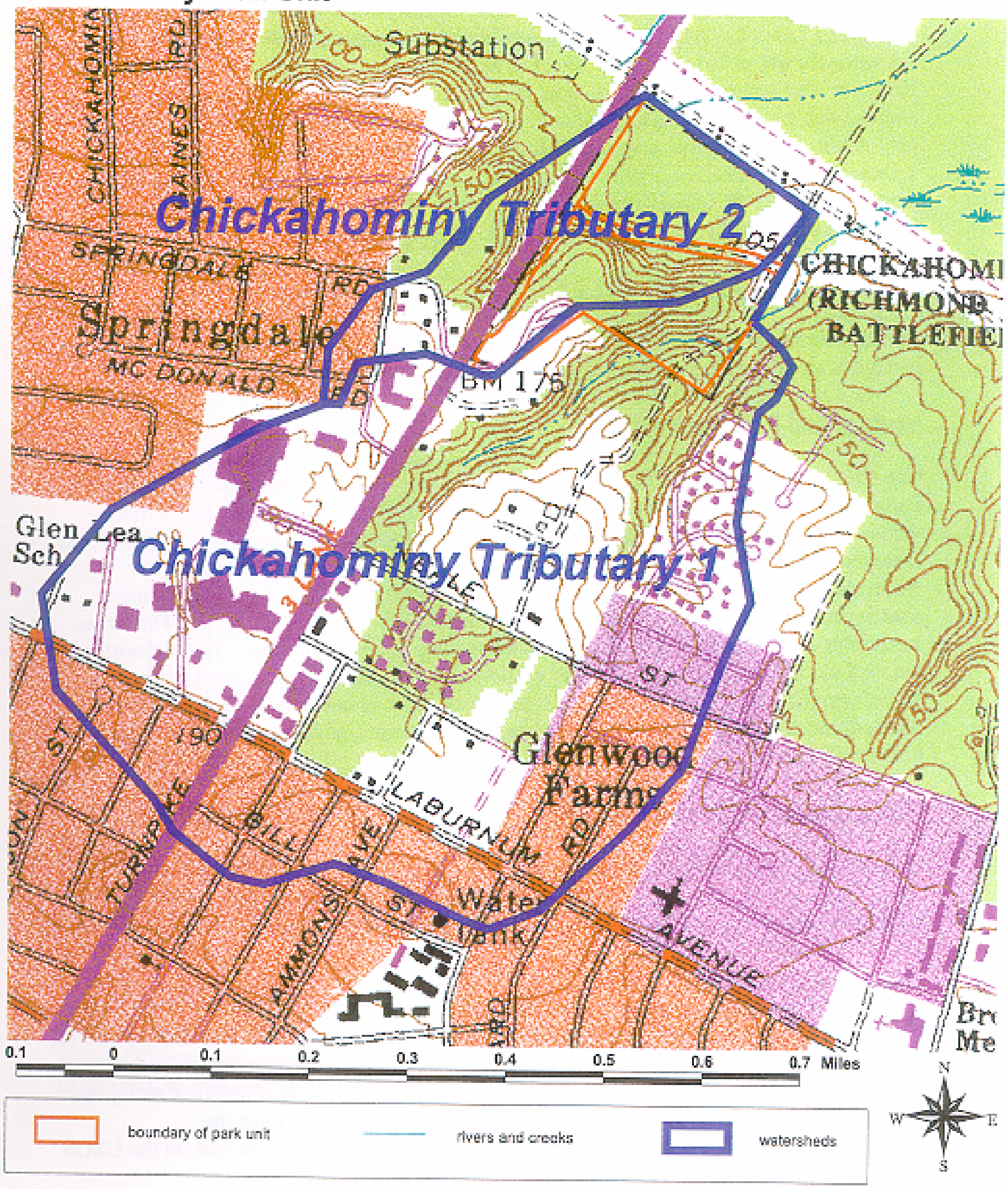

Figure 14. Map showing watershed contributing to the Chickahominy Bluff unit.

According to the STORET data in the Baseline Report (National Park Service 1999), no surface-water quality monitoring stations are within the current boundary of the unit. However, the Level I WAQIM implemented a station in the Chickahominy Bluff unit. Sampling occurred quarterly from August 2001 to April 2002. See Appendix C for the results of this study. Table 4 summarizes water quality data collected from Tributary 1 during this Level I WAQIM. No State water quality standards were exceeded except the 5.8 value for pH in January 2002, which is below the State standard of 6.0 pH units. However, this stream and most streams in other units of the park drain low-gradient and/or swampy areas containing naturally high concentrations of organic acids that lower pH. Additionally, the low alkalinity values and low acid neutralizing capacity for Tributary 1 are indicative of swampy areas and help to explain the lower pH. All other parameter values are unremarkable. The suite of water quality parameters does not indicate a strong influence from surrounding land use.

Ground-Water Resources

Ground-water resources have not been developed at this unit. The lowest areas serve as ground-water discharge zones to the Chickahominy River and associated wetlands.

Wetland and Riparian Resources

The Chickahominy Bluff unit contains approximately 12 acres of seasonally flooded Palustrine wetland, which is part of the Chickahominy River floodplain. Palustrine wetlands are non-tidal and dominated by trees, shrubs, persistent emergent vegetation and emergent mosses or lichens (Cowardin *et al.* 1979). Seasonally flooded refers to wetlands in which surface water is present for extended periods during the growing season, but is often absent by the end of the summer (Cowardin *et al.* 1979). The larger wetland is divided into smaller sections with various community types. The majority of the wetland is forested, however small portions are dominated by persistent emergents and evergreen and deciduous broad-leaved shrubs. The forested areas of wetland are divided into communities dominated by deciduous species, and communities containing both deciduous and evergreen species.

Water Supply and Sewage Disposal

No such infrastructure exists at this unit.

COLD HARBOR

Watershed Description

The main stream that flows through roughly the middle portion of the Cold Harbor unit is Bloody Run, a tributary to Powhite Creek (Figure 15). An unnamed tributary to Powhite Creek forms part of the northern boundary of the Cold Harbor unit. Powhite Creek joins the Chickahominy River just upstream of where Boatswain Creek joins the Chickahominy River. No other perennial streams are shown within the unit on the USGS

Table 4. Results of surface-water samples collected from Tributary 1 (Figure 14) of the Chickahominy Bluff unit during the 2001-2002 Level I WAQIM. Not all water quality parameter results are shown. Refer to Appendix C for complete water quality parameter results and sample location.

Water-Quality Parameter, unit	**Range, Sample Size**
Discharge, ft^3/s	0.01-0.64, n=3
Dissolved oxygen, mg/L	7.4-10.6, n=4
Field pH, standard units	5.8-6.5, n=4
Specific conductance, µS/cm	117-172, n=4
Water temperature, ºC	8.9-23.4, n=4
Alkalinity, mg/L as $CaCO_3$	7-13, n=4
Dissolved calcium, mg/L	7.82, n=1
Dissolved magnesium, mg/L	2.43, n=1
Dissolved potassium, mg/L	2.66, n=1
Dissolved sodium, mg/L	14.2, n=1
Unfiltered acid neutralizing capacity, mg/L as $CaCO_3$	15, n=1
Dissolved chloride, mg/L	25.5, n=1
Dissolved fluoride, mg/L	0.01, n=1
Dissolved silica, mg/L	10.3, n=1
Dissolved ammonia, mg/L as NH_4	0.033-0.114, n=4
Total phosphorus, mg/L	0.006-0.094, n=4
Fecal coliform, col./100 mL	67-680, n=4
Aluminum, µg/L	25, n=1
Lead, µg/L	<1, n=1
Mercury, µg/L	<0.01
Dissolved iron, µg/L	250, n=1
Dissolved manganese, µg/L	18, n=1

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; n=, number of samples; °C, degrees Celsius; col, colonies; µS/cm, microsiemens per centimeter at 25 °C; $CaCO_3$, calcium carbonate; NH_4, ammonium; µg/L, micrograms per liter]

1:24,000-scale topographic map, although the rolling topography suggests that ephemeral tributaries and wetlands exist during and shortly after storms. The Cretaceous-age Patuxent Formation, which underlies the park units, holds "a significant amount of water" in the 100- to 300-foot thick aquifer (National Park Service 1996).

Watersheds
Gaines Mill and Cold Harbor Units

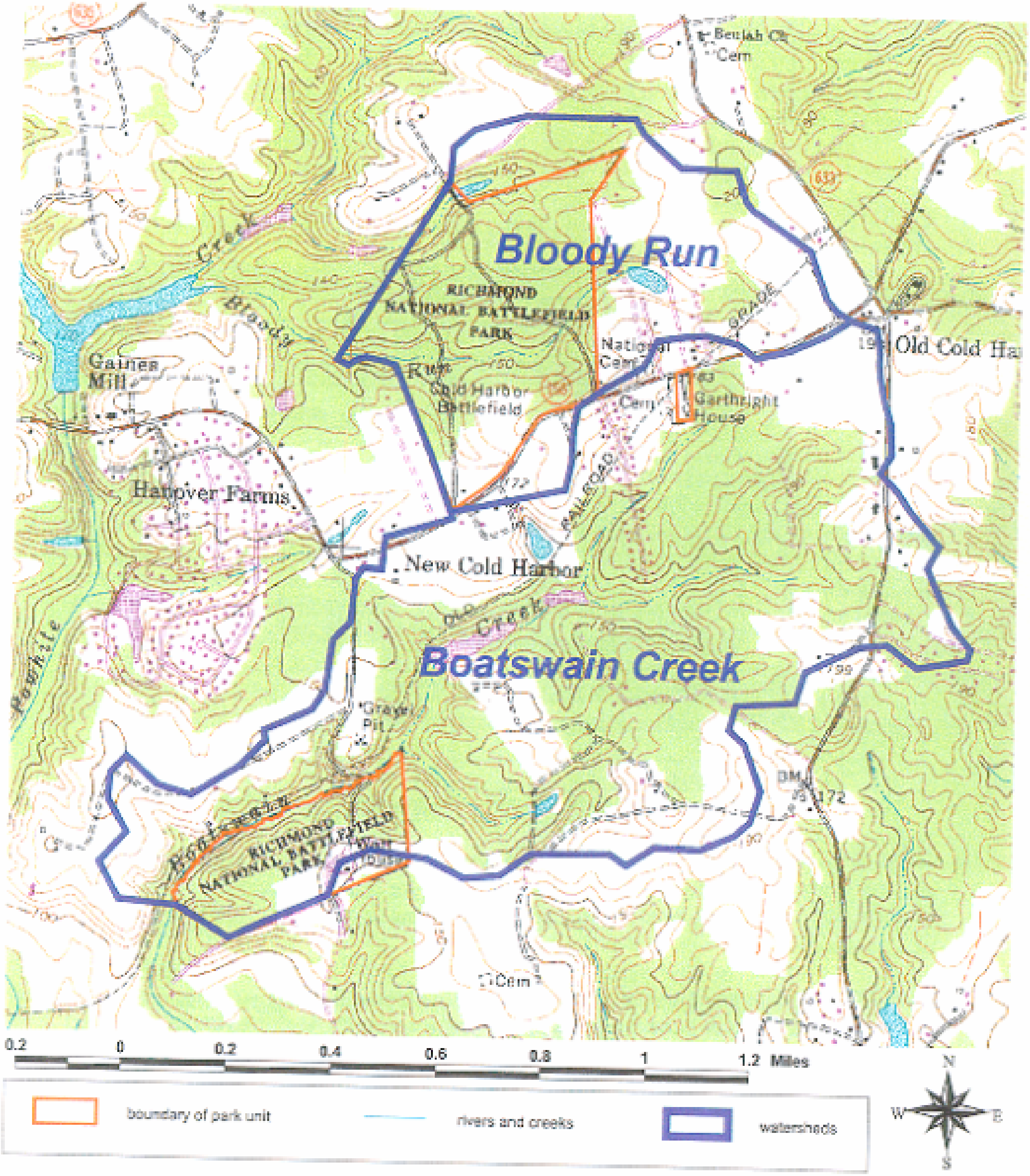

Figure 15. Map showing watershed contributing to the Cold Harbor unit, the Garthright House and the Gaines' Mill unit.

Surface-Water Resources

As described above, the unit has one main perennial stream, Bloody Run, and a small headwater tributary to Powhite Creek. No stream-gaging stations exist within the Cold Harbor unit, so no direct information about surface-water quantity is available. The surface-water hydrograph will be similar in shape to that shown in Figure 12, as described above.

No wastewater dischargers, drinking-water intakes, water gages or impoundments are located within the current boundaries of the Cold Harbor unit (National Park Service 1999). Surface water draining the Cold Harbor unit is impounded downstream in Gaines' Mill Pond by an earthen dam (state numbering system VA08506) that was completed in 1850 (National Park Service 1999).

In 1987, the National Park Service performed water testing for the parasitic amoeba *Naegleria fowleri* within the unit, but none were found (documents on file at Richmond NBP).

In 1996, temperature, pH, dissolved oxygen, specific conductance, redox potential, and hardness were determined (data sheets on file at Richmond NBP).

According to the STORET data in the Baseline report (National Park Service 1999), no surface-water quality monitoring stations are located within the current boundaries of the unit. However, with the implementation of the Level I WAQIM, two water quality stations were established on Bloody Run – one each at the eastern and western park boundaries. Sampling occurred quarterly from August 2001 to April 2002. See Appendix C for the results of this sampling. Table 5 summarizes water quality data collected from Bloody Run during this Level I WAQIM. No State water quality standards were exceeded except all pH values were consistently below the standard of pH value of 6.0 and three values were below a pH of 5. See the explanation under BEAVER DAM CREEK for a discussion of these potentially naturally occurring low pH values. However, pH values below 5.0 are approaching a critical limit for some aquatic flora and fauna. At pH 5.5 bottom-dwelling bacterial decomposers begin to die and leave non-decomposed leaf litter and other organic debris to collect on the bottom. At pH 5.0 most fish eggs cannot hatch; below a pH 4.5 adult fish die. As pH decreases there is commonly a concomitant increase in aluminum levels. Aluminum is mobilized from the sediments, where it previously was sequestered. Increased aluminum levels may be directly toxic to fish. In Bloody Run aluminum levels were elevated but those levels rank fourth out of the seven units sampled. Any future water-quality monitoring program in the park should consider the aluminum as a monitoring parameter. If pH values across all units of the park would decrease further, suggesting anthropogenic insults (i.e., acid deposition), the measurement of aluminum would be important in understanding biological impacts.

Three dissolved oxygen values were below the 4.0 mg/l standard; however, these were associated with no-to-minimal water flow and represent stagnant conditions. All other

Table 5. Results of surface-water samples collected from Bloody Run of the Cold Harbor unit during the 2001-2002 Level I WAQIM. Not all water quality parameter results are shown. Refer to Appendix C for complete water quality parameter results and sample locations.

Water-Quality Parameter, unit	**Bloody Run East Range, Sample Size**	**Bloody Run West Range, Sample Size**
Discharge, ft^3/s	0-0.01, n=2	0.13-0.59, n=4
Dissolved oxygen, mg/L	0.8-5.3, n=4	5.6-10.3, n=4
Field pH, standard units	4.8-5.8, n=4	4.7-5.6, n=4
Specific conductance, µS/cm	44-73, n=4	61-70, n=4
Water temperature, ºC	8-20.4, n=4	5.4-19.8, n=4
Alkalinity, mg/L as $CaCO_3$	5-22, n=4	2.4, n=4
Dissolved calcium, mg/L	2.58, n=1	1.11, n=1
Dissolved magnesium, mg/L	1.77, n=1	2.81, n=1
Dissolved potassium, mg/L	1.49, n=1	1.36, n=1
Dissolved sodium, mg/L	4, n=1	5.9, n=1
Unfiltered acid neutralizing capacity, mg/L as $CaCO_3$	18, n=1	5, n=1
Dissolved chloride, mg/L	5.3, n=1	9.6, n=1
Dissolved fluoride, mg/L	<0.1, n=1	<0.1, n=1
Dissolved silica, mg/L	8.8, n=1	7.5, n=1
Dissolved ammonia, mg/L as NH_4	0.022-0.135, n=4	0.021-0.040, n=4
Total phosphorus, mg/L	0.018-0.089, n=4	0.007-0.013, n=4
Fecal coliform, col/100 mL	10-95, n=4	87-570, n=4
Aluminum, µg/L	255, n=1	116, n=1
Lead, µg/L	2, n=1	present, n=1
Mercury, µg/L	0.01, n=1	<0.01, n=1
Dissolved iron, µg/L	11100, n=1	270, n=1
Dissolved manganese, µg/L	205, n=1	29, n=1

[ft^3/s, cubic feet per second; mg/L, milligrams per liter; n=, number of samples; °C, degrees Celsius; col. colonies; µS/cm, microsiemens per centimeter at 25 °C; $CaCO_3$, calcium carbonate; NH_4, ammonium; µg/L, micrograms per liter]

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parameter values are unremarkable. This suite of water quality parameters does not indicate a strong influence from surrounding land use.

Ground-Water Resources

From October 1983 to March 1988, ground-water-level monitoring was conducted in a well owned by the National Park Service used for public water supply at the Cold Harbor Visitor's Center. The well was drilled in 1962 to a depth of 280 feet below land surface, with 6-inch diameter well casing to a depth of 10 feet, 4-inch casing from 10-255 feet, a screened interval from 255-275 feet, and a 4-inch tailpipe from 275-276.4 feet (David Nelms, USGS, pers. comm. 2000). The well, referred to as well 52J 10 by USGS (and well 142-005 by Virginia DEQ), yields water from a confined aquifer, the Middle Potomac aquifer of Cretaceous age. USGS made a water-level measurement in the well in December 1972 when a water-quality sample was collected, and periodic measurements were made roughly every 3-4 months from October 1983 to March 1988. During 1988, well 52J 10 was abandoned due to fecal coliform contamination and a new well (52J 56) was installed approximately 16 feet to the southwest. Well 52J 56 was drilled to a depth of 270 feet below land surface, with a 4-inch diameter well casing to 265 feet, and screened intervals from 210 to 220 feet and from 250 to 260 feet. Well 52J 56 also yields water from the Middle Potomac aquifer (White *et al.* 2001). The next closest water-level monitoring well to the Cold Harbor unit with published records is in Henrico County at Highland Springs, approximately 3 miles to the southwest of the well at the Visitor's Center (White and Powell 2000).

Water level in wells 52J 10 and 52J 56 at the Cold Harbor Visitor's Center is affected by regional drawdown in the confined aquifer. The highest water level measured in 52J 10 was 165.75 feet below land-surface datum on December 1, 1972; the lowest water level measured was 209.44 feet below land-surface datum on September 9, 1999 (White and Powell 2000). In well 52J 56, the highest water level measured was 177.20 feet below land-surface datum on December 13, 1995; the lowest water level measured was 209.44 feet below land-surface datum on September 9, 1999 (White *et al.* 2001). The water level systematically declined from 1983 through August 1994, recovered from September 1994 to March 1995, then declined at a faster rate from March 1995 to 1999, with a gradual increase to the present (Figure 16). The recovery period from September 1994 to March 1995 coincided with a cessation of the use of the well for water supply at the Visitor's Center (T. Scott Bruce, Virginia DEQ, pers. comm. 2000 and confirmed by Jerry Helton, Richmond NBP, pers. comm. 2000). The decline in water level starting in March 1995 is likely due to increased pumping from another well that taps the same aquifer, possibly a well located near the Garthright House, installed in 1988, which taps the same aquifer at a depth of 305 feet. This well began to be used for public water supply for Hanover County starting in March 1995 (T. Scott Bruce, Virginia DEQ, pers. comm. 2000 and David Nelms, USGS, pers. comm. 2000).

Historians speculate that ground-water levels in the unconfined aquifer in this area were higher during the Civil War than they are in modern times. A letter written in 1987 by the late Mr. William F. Mallory of Richmond provides an account of the 1953 meeting between the Richmond and Chicago Civil War Roundtables. During that meeting, Dr. Douglas S. Freeman of Richmond stated from personal knowledge that the water table in

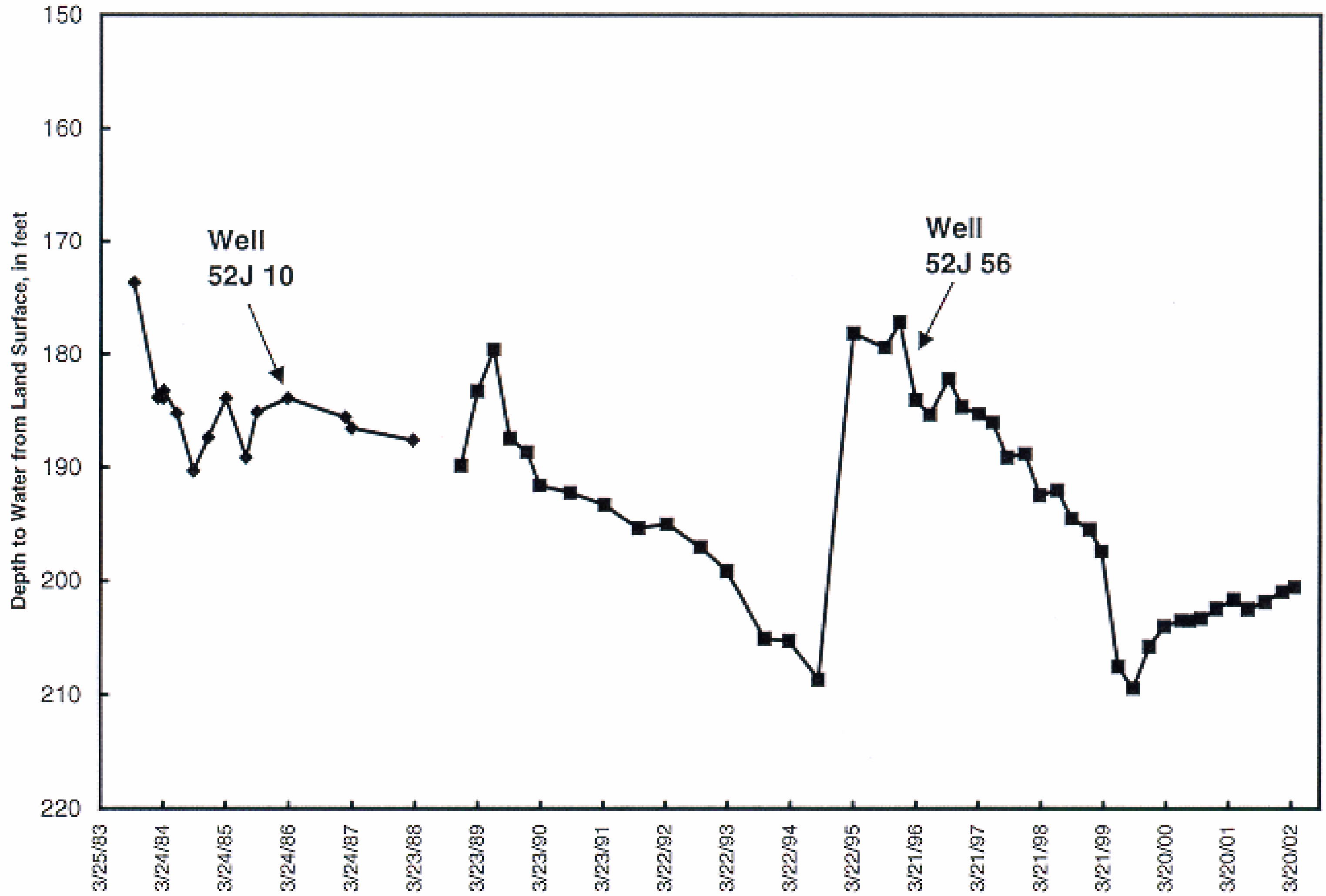

Figure 16. Water-level measurements in wells at Cold Harbor Visitor's Center, 1983-2002.

the 1860's were probably about 40% higher than it is now. Dr. Freeman speculated that swampy areas had been drained to "reclaim" the land, presumably for agricultural use.

This speculation provides an oral history that is in agreement with soldiers' accounts of the difficult, swampy conditions encountered during the war. Dr. Freeman also suggested that an increase in population in the area, with the accompanying need for potable water, and the use of ground water for irrigation by truck farms caused the water table to be lower relative to its position during the Civil War. Although Dr. Freeman likely was referring to the unconfined aquifer, direct observations of more recent water levels in a confined aquifer in this area demonstrate that water levels have declined due to pumping of the aquifer (Figure 16).

Only one ground-water quality sample is available for the Cold Harbor unit. According to USGS records, well 52J 10 was sampled on August 30, 1984 (Table 6).

Table 6. Results of ground-water samples collected in well 52J 10 in the Cold Harbor unit, August 1984.

Water-Quality Parameter, unit	Concentration or Measurement
Water temperature, °C	20
Specific conductance, µS/cm	230
pH, units	7.4
Oxygen, mg/L	0.7 (8% saturation)
Carbonate, mg/L	102
Nitrogen, (NO_2 + NO_3), mg/L	0.17
Total hardness, mg/L as $CaCO_3$	63
Calcium, mg/L	17
Magnesium, mg/L	5.1
Sodium, mg/L	12
Potassium, mg/L	15
Chloride, mg/L	1.8
Sulfate, mg/L	7.3
Fluoride, mg/L	0.1
Silica, mg/L	13
Iron, µg/L	1,600
Manganese, µg/L	37
Zinc, µg/L	200
Aluminum, µg/L	200

[All concentrations are dissolved, unless otherwise noted; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; $NO_2 + NO_3$, nitrite plus nitrate; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter]

Wetland and Riparian Resources

Three wetland areas are delineated on the NWI map (Seven Pines) for the Cold Harbor unit and one wetland is delineated near the Garthright House; all four are classified as palustrine. The three wetland types in the Cold Harbor unit are described as broad-leaved deciduous palustrine wetlands. As expected, palustrine wetlands are the dominant type of wetland (100%) because of the forest cover in the Cold Harbor unit. Palustrine wetlands are non-tidal and dominated by trees, shrubs, persistent emergent vegetation and emergent mosses or lichens (Cowardin *et al.* 1979). Of these areas, one wetland is classified as temporarily flooded, one is classified as seasonally flooded, and the one mapped along Bloody Run is classified as seasonally flooded/saturated. The wetland at the Garthright House is mapped as farmed palustrine. Broad-leaved deciduous refers to dominant trees such red maple, American elm (*Ulmus americana*), and ashes (*Fraxius* spp.), among others. Temporarily flooded refers to wetlands in which surface water is present for brief periods during the growing season, but where the water table usually lies well below the soil surface for most of the season. Seasonally flooded refers to wetlands in which surface water is present for extended periods, especially early in the growing season, but is absent by the end of the growing season in most years.

Water Supply and Sewage Disposal

Prior to 1989, well 52J 10 was used for public water supply, as discussed in the Ground Water section, above. In 1988, a new well (52J 56) was installed at the Visitor's Center for public water supply, as the old well was declared "unusable" by the Virginia DEQ because of fecal coliform contamination (files at Richmond NBP). Well 52J 56 is approximately 16 feet to the southwest of the old well (site map on file at Richmond NBP). During 1991, water from well 52J 56 was reportedly in exceedence of the total coliform standard; it was shock treated with chlorine (scoping report file at WRD/NPS, Ft. Collins). In 1994, the Cold Harbor Visitor's Center was connected to Hanover County public water supply (Jerry Helton, Richmond NBP, pers. comm. 2000). The transition from the well to the county for public water supply likely occurred during late 1994, as indicated by the recovery in ground-water level from September 1994 to March 1995 in adjacent well 52J 56 (Figure 16). A new well was installed at the Garthright House in 1990, with a depth of 305 feet and the pump at 273 feet (scoping report file at WRD/NPS, Ft. Collins).

A fairly new, properly designed septic system with three drain fields is in use at the Cold Harbor Visitor's Center (David McKinny, Richmond NBP, pers. comm. 2000). The septic system at the Garthright House was replaced in 1990 (Sharrow, no date).

DREWRY'S BLUFF

Watershed Description

The Drewry's Bluff unit is located within the James River watershed, with its northeast boundary consisting of a cliff-like 1,000-foot section of the southwestern bank of the James River. This unit is surrounded on all sides by heavy industrial development (i.e. industry consisting of outdoor operations). A small unnamed tributary (not marked on 1994 USGS topographic quadrangle) drains an asphalt plant adjacent to the park's western boundary, flows through the unit for approximately 1,200 feet and empties into the James River (Figure 17). It exits the park at its eastern boundary, approximately 700 feet from the James River. The southeastern section of the unit consists of a closed, 5-acre landfill donated to the park by Chesterfield County in the early 1970's. It appears that leachate from the landfill is having an impact on the unnamed tributary.

Surface-Water Resources

As described above, the main surface-water body in the unit is the small, unnamed tributary that drains the asphalt plant. This stream may be impacted by the landfill, before it flows into the James River.

No stream-gaging stations exist within the Drewry's Bluff unit, so no direct information about surface-water quantity is available. The surface-water hydrograph will be similar in shape to that shown in Figure 12, as described above.

The implementation of the Level I WAQIM established three water quality monitoring stations on the unnamed tributary. Sampling occurred quarterly from August 2001 to April 2002. See Appendix C for the results of this sampling. Table 7 summarizes the water quality data collected from the unnamed tributary during the Level I WAQIM assessment. No water quality standards were exceeded except for pH and dissolved oxygen. Five out of 12 pH samples were below the state standard of pH value of 6.0. It is unclear whether these low pH values are naturally occurring (see discussion under BEAVER DAM CREEK) given the two potential nonpoint sources of water pollution (i.e., the landfill and the asphalt plant). It is interesting to note that the lowest pH values occurred at the west site that is closest to the asphalt plant. The dissolved oxygen standard of 4.0 mg/L was exceeded in six out of 12 samples; however, those exceedances were associated with no-to-minimal flow and therefore were associated with stagnant conditions.

Of particular note for Drewry's Bluff are the spatio-temporal trends in water quality parameters, given the limited sampling under the Level I WAQIM. Alkalinity values and specific conductance at Drewry's Bluff were the highest of any of the units in the park, with the middle site having the highest values. Dissolved ammonia levels were the highest of any unit, with levels at the middle and east sites consistently greater than the suggested EPA criterion of 2.0 mg/L for streams; values peaked at the middle site (closest to the landfill). It should be noted that there are State acute and chronic

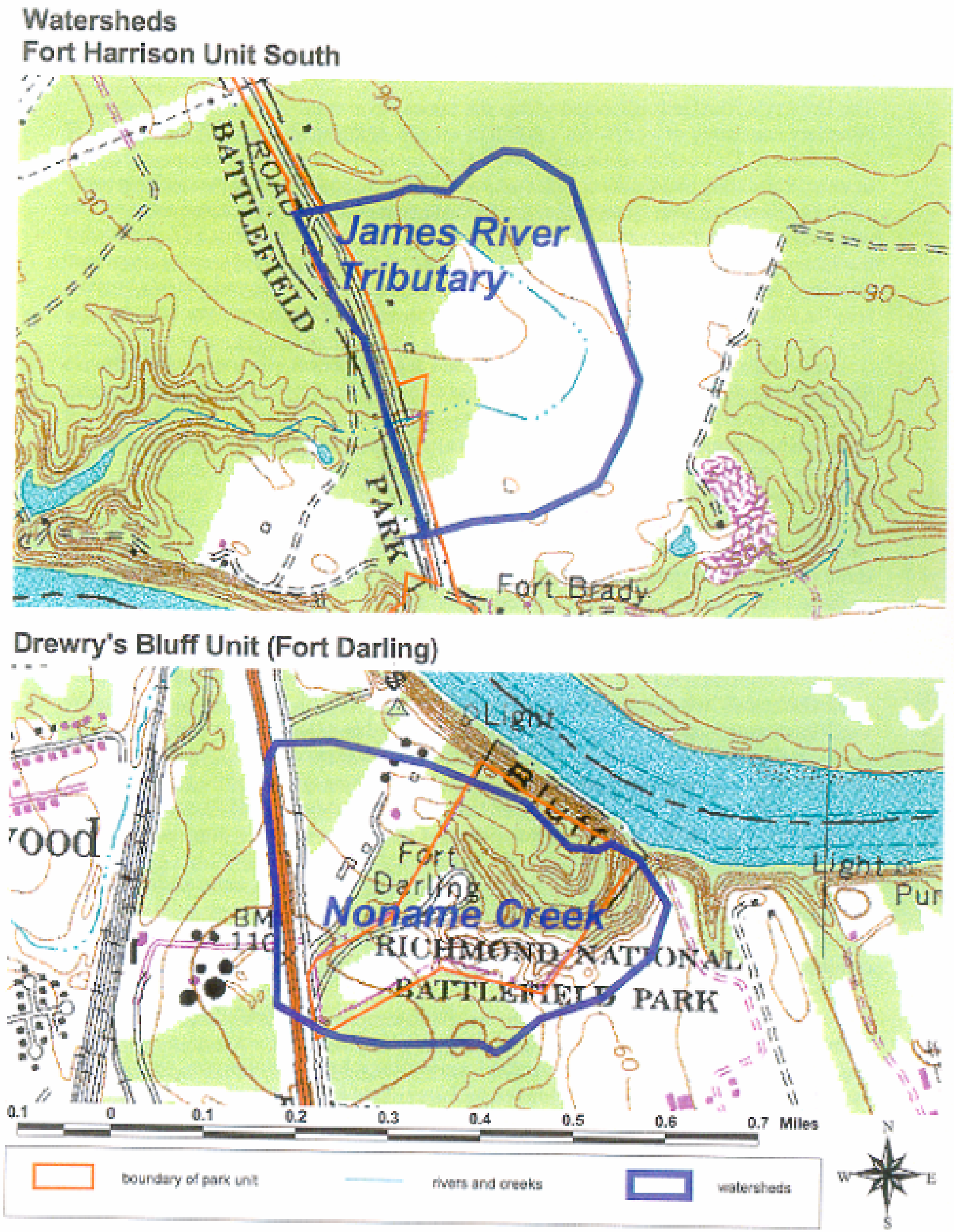

Figure 17. Map showing watershed contributing to the southern section of the Fort Harrison unit and the Drewry's Bluff unit.

freshwater standards for ammonia, but these are based on pH values of 6.5 or higher (Apppendix B). It is therefore not possible to determine if dissolved ammonia levels exceeded one or more State standards. Values for the following parameters were consistently the highest of all other sites and their values always peaked at the middle site: calcium, magnesium, potassium, sodium, chloride, silica, barium, boron, cobalt, iron, manganese, and nickel. Total phosphorus was elevated (over seven times greater than the suggested EPA criterion of 0.1 mg/L for streams) for the April 2002 sampling date at the west site. This suggests some runoff related or point source event occurred in the area of the asphalt plant.

The above spatio-temporal trends in water quality parameters suggest that land use impacts are occurring. Impacts may be point- or nonpoint-source related in connection with the asphalt plant and nonpoint-source related in connection with the landfill.

In 1987, the National Park Service performed water testing for the parasitic amoeba *Naegleria fowleri* within the unit, but none were found (documents on file at Richmond NBP).

Table 7. Results of surface-water samples collected from the unnamed triburary (Figure 17) of the Drewry's Bluff unit during the 2001-2002 Level I WAQIM. Not all water quality parameter results are shown. Refer to Appendix C for complete water quality parameter results and site locations.

Water-Quality Parameter, unit	West Site Range, Sample Size	Middle Site Range, Sample Size	East Site Range, Sample Size
Discharge, ft^3/s	0.04, n=1	0.19, n=1	0.23, n=1
Dissolved oxygen, mg/L	0.3-10.2, n=4	0.3-8.6, n=4	4-7.9, n=4
Field pH, standard units	5.5-9, n=4	5.8-6.5, n=4	6.0-6.6, n=4
Specific conductance, µS/cm	124-3900, n=4	645-830, n=4	403-476, n=4
Water temperature, ºC	10.9-21.2, n=4	12.7-21.2, n=4	12.3=20.9, n=4
Alkalinity, mg/L as $CaCO_3$	19-68, n=4	31-292, n=4	70-84, n=4
Dissolved calcium, mg/L	5.22, n=1	11.3, n=1	14.6, n=1
Dissolved magnesium, mg/L	1.84, n=1	7.65, n=1	8.66, n=1
Dissolved potassium, mg/L	2.94, n=2	13.9, n=1	11.3, n=1
Dissolved sodium, mg/L	13.8, n=1	69.8, n=1	32.5, n=1
Acid neutralizing capacity, mg/L as $CaCO_3$	36, n=1	163, n=1	74, n=1
Dissolved chloride, mg/L	10.4, n=1	94.2, n=1	70.2, n=1
Dissolved fluoride, mg/L	<0.1, n=1	<0.1, n=1	0.1, n=1

Dissolved silica, mg/L	15.9, n=1	6.8, n=1	14.1, n=1
Dissolved sulfate, mg/L	--	--	1.8 – 14, n=46
Dissolved solids, mg/L	--	--	32 – 83, n=11
Dissolved ammonia, mg/L as NH_4	0.04-0.211, n=4	0.04-11.1, n=4	2.65-3.99, n=4
Total phosphorus, mg/L	0.027-0.755, n=4	0.049-0.094, n=4	0.008-0.034, n=4
Fecal coliform, col./100 mL	28-950, n=4	3-330, n=4	3-400, n=4
Dissolved iron, µg/L	883, n=1	78100, n=1	4210, n=1
Lead, µg/L	0.52, n=1	<1, n=1	<1, n=1
Dissolved manganese, µg/L	832, n=1	3750, n=1	1590, n=1

[ft^3/s, cubic feet per second; n=, number of samples; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; col., colonies; $CaCO_3$, calcium carbonate; NH_4, ammonium; µg/L, micrograms per liter; --, no data]

In 1996, temperature, pH, dissolved oxygen, specific conductance, redox potential, and hardness were determined (data sheets on file at Richmond NBP).

Ground-Water Resources

Ground-water resources have not been developed at this unit. The area probably serves as a regional ground-water discharge zone because of the proximity of the James River. Specific information about ground-water quality in and adjacent to the landfill can be found in the section entitled "Adopting a Proactive Culture to Protect Park Lands".

Wetland and Riparian Resources

No wetlands are delineated in this unit by the NWI map or Johnson *et al.* (1994).

Water Supply and Sewage Disposal

A well was installed in 1977 to a depth of 200 feet (Sharrow, no date). No other water-supply or sewage disposal infrastructure exists at this unit.

FORT HARRISON

Watershed Description

The Fort Harrison unit is located within the James River watershed. As a 7-mile linear parcel, several tributaries of the James River intersect it, including Cornelius Creek at its northern end, Coles Run at its central area, and a small, unnamed headwater stream at its southern end (Figures 17, 18). In addition, the southern boundary of the unit is directly adjacent to the James River. However, because the unit is very narrow along most of its length (approximately 100 feet wide on average), Cornelius Creek and the small, unnamed stream are within park boundaries for very limited distances. However, the wider central area of the unit is included in the Coles Run watershed. An unnamed tributary to Coles Run drains a small, forested wetland within park boundaries. Water tends to gather in low areas and roadside ditches during, and several weeks following, precipitation events. Land use surrounding the Fort Harrison unit and the tributaries intersecting it includes agriculture and rural residential development.

<u>Surface-Water Resources</u>

No stream-gaging stations exist within the Fort Harrison unit, so no direct information about surface-water quantity is available. The surface-water hydrograph will be similar in shape to that shown in Figure 12, as described above.

According to the STORET data in the Baseline report (National Park Service 1999), no surface-water quality monitoring stations are located within the current boundaries of the unit. However, with the implementation of the Level I WAQIM, two water quality stations were established -- one on a tributary to Coles Run and one along Battlefield Park Road in ponded water. Sampling occurred quarterly from August 2001 to April 2002 in the ponded area but only in January 2002 for the tributary. See Appendix C for the results of this sampling. Table 8 summarizes the water quality data collected from the Fort Harrison unit during the Level I WAQIM. No State water quality standards were exceeded except pH where all values at both stations were consistently below the State standard of 6.0 pH units. Additionally, these pH values were the lowest of all park units sampled. See the explanation under the BEAVER DAM CREEK for a discussion of these apparently naturally occurring low pH values. Additionally, dissolved oxygen was well below the 4.0 mg/L State standard for all values at the ponded locale, and is attributable to stagnant conditions associated with no flow. Dissolved ammonia for the ponded water site was below the suggested 2.0 mg/L criterion level; however, values were the second highest of all park units sampled. Given the stagnant, acidic conditions at this site, the higher ammonia levels are probably a result of organic decomposition. Total phosphorus levels exceeded the suggested EPA criterion level of 0.1 mg/L for all samples at the ponded site. These higher total phosphorus levels suggest that impacts from surrounding land use may be occurring. In this case fertilizers used on residential lawns may be flushed during runoff events. The ponded site also had the highest aluminum value of all sampled units in the park. This is probably a result of the very low pH values – aluminum is mobilized out of the sediments under acidic conditions. These acidic conditions may also explain the high lead, nickel, chromium, cobalt, and iron values; lead, chromium and cobalt values were the highest of all sampled units. However, their higher values could also be related to surrounding land use.

In 1987, the National Park Service performed water testing for the parasitic amoeba *Naegleria fowleri* within the unit, but none were found (documents on file at Richmond NBP).

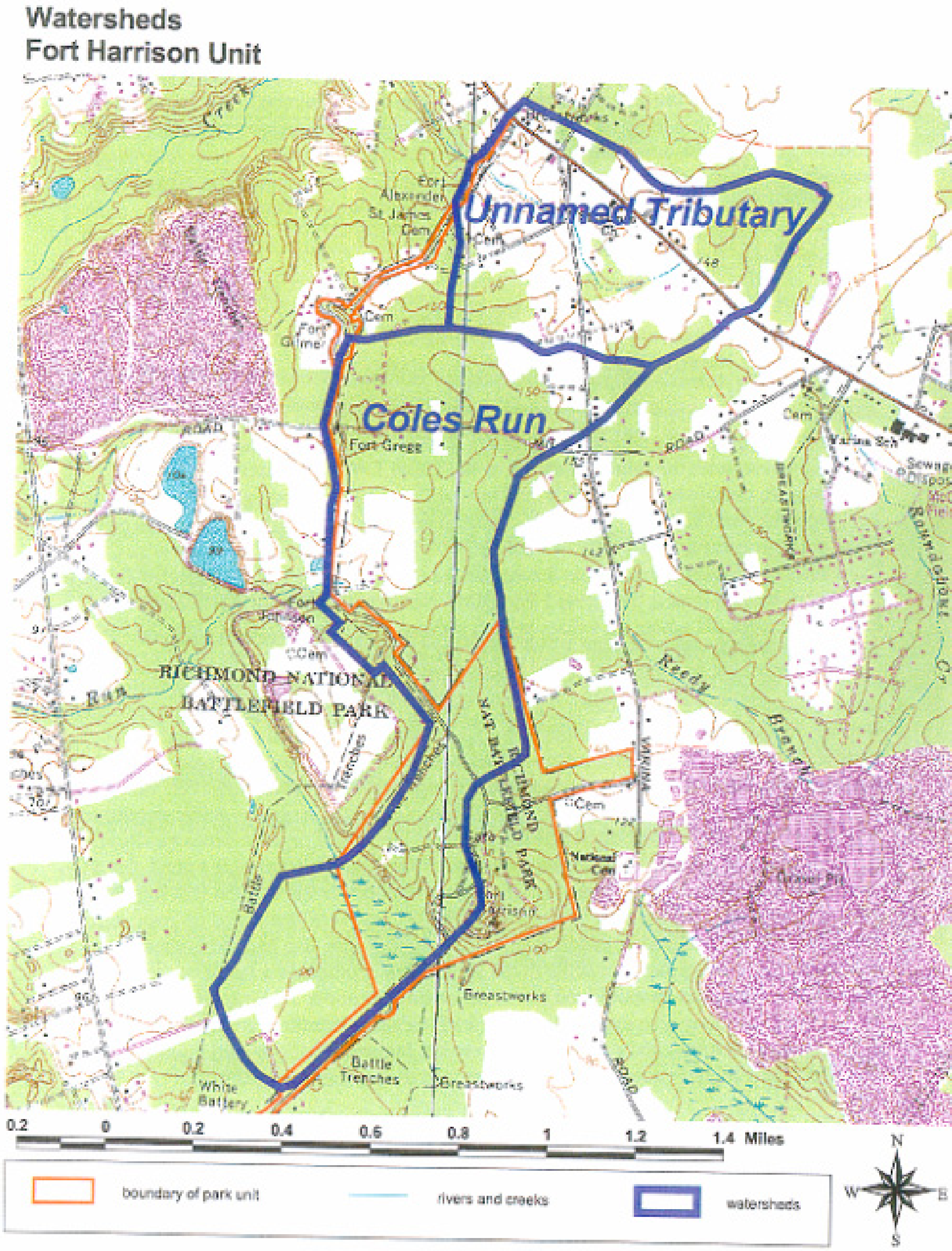

Figure 18. Map showing watershed contributing to the northern section of the Fort Harrison unit.

Table 8. Results of surface-water samples collected from the Fort Harrison unit during the 2001-2002 Level I WAQIM. Not all water quality parameter results are shown. Refer to Appendix C for complete water quality parameter results and site locations.

Water-Quality Parameter, unit	**Seasonal Tributary Range, Sample Size**	**Ponded Water along Battlefield Park Rd. Range, Sample Size**
Discharge, ft^3/s	0.18, n=1	0, n=4
Dissolved oxygen, mg/L	6.3, n=1	0.3-0.9, n=4
Field pH, standard units	4.1, n=1	4.5-5.3, n=4
Specific conductance, µS/cm	66, n=1	35-56, n=4
Water temperature, ºC	14.1, n=1	9.4-22.7, n=4
Alkalinity, mg/L as $CaCO_3$	1, n=1	1-5, n=4
Dissolved calcium, mg/L	---	1.57, n=1
Dissolved magnesium, mg/L	---	1.08, n=1
Dissolved potassium, mg/L	---	3.22, n=1
Dissolved sodium, mg/L	---	1.9, n=1
Unfiltered acid neutralizing capacity, mg/L as $CaCO_3$	---	8, n=1
Dissolved chloride, mg/L	---	5.1, n=1
Dissolved fluoride, mg/L	---	<0.1, n=1
Dissolved silica, mg/L	---	8, n=1
Dissolved sulfate, mg/L	---	0.7, n=1
Dissolved ammonia, mg/L as NH_4	<0.04, n=1	0.277-0.643, n=4
Total phosphorus, mg/L	0.011, n=1	0.165-0.413, n=4
Fecal coliform, col./100 mL	220, n=1	5-510, n=4
Aluminum, µg/L	---	2010, n=1
Dissolved iron, µg/L	---	2760, n=1
Lead, µg/L	---	12, n=1
Dissolved manganese, µg/L	---	296, n=1

[n=, number of samples; °C, degrees Celsius; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; col., colonies; $CaCO_3$, calcium carbonate; NH_4, ammonium; µg/L, micrograms per liter; --, no data]

Ground-Water Resources

Two wells owned by the USGS (52H 16, 52H 17) are located within the Fort Harrison unit and are used by Virginia DEQ for ground-water-level monitoring. Both wells are located approximately 800 feet east of the visitor's center at a land-surface datum elevation of 135 feet above sea level. Virginia DEQ has made water-level measurements in these wells approximately quarterly since November 1995 (White *et al.* 2001; Figure 19).

Well 52H 16 was drilled in 1995 to a depth of 34.25 feet below land surface, with a 2-inch diameter well casing and a screened interval from 24.25-34.25 feet (White *et al.* 2001). This well yields water from the Yorktown-Eastover aquifer of Miocene-Pliocene age (White *et al.* 2001). The highest water level measured was 12.80 feet below land-surface datum on January 17, 2000, and the lowest measured was 26.27 feet below land-surface datum on November 13, 1995 (White *et al.* 2001).

Well 52H 17 also was drilled in 1995 with a 2-inch diameter well casing. The depth is 78.90 feet below land surface, with a screened interval of 73.90-78.90 feet (White *et al.* 2001). This well yields water from the Aquia aquifer of Paleocene age (White *et al.* 2001). The highest water level measured was 46.63 feet below land-surface datum on May 5, 1997, and the lowest measured was 54.44 feet below land-surface datum on October 21, 1997 *(*White *et* al. 2001).

Wetland and Riparian Resources

The Fort Harrison unit contains four small wetlands in the central section of the unit. All four are classified as forested, palustrine wetlands. Palustrine wetlands are non-tidal and dominated by trees, shrubs, persistent emergent vegetation and emergent mosses or lichens (Cowardin *et al.* 1979). Two of the wetlands, both drained by tributaries of Coles Run (see "Watershed Description"), are classified as temporarily flooded and are inhabited by a forest community dominated by both broad-leaved deciduous and evergreen trees. Temporarily flooded refers to wetlands in which surface water is present for brief periods during the growing season, but where the water table usually lies well below the soil surface for most of the season. The other two wetlands farther east are classified as seasonally flooded and are dominated by broad-leaved deciduous trees. Seasonally flooded refers to wetlands in which surface water is present for extended periods during the growing season, but is often absent by the end of the summer.

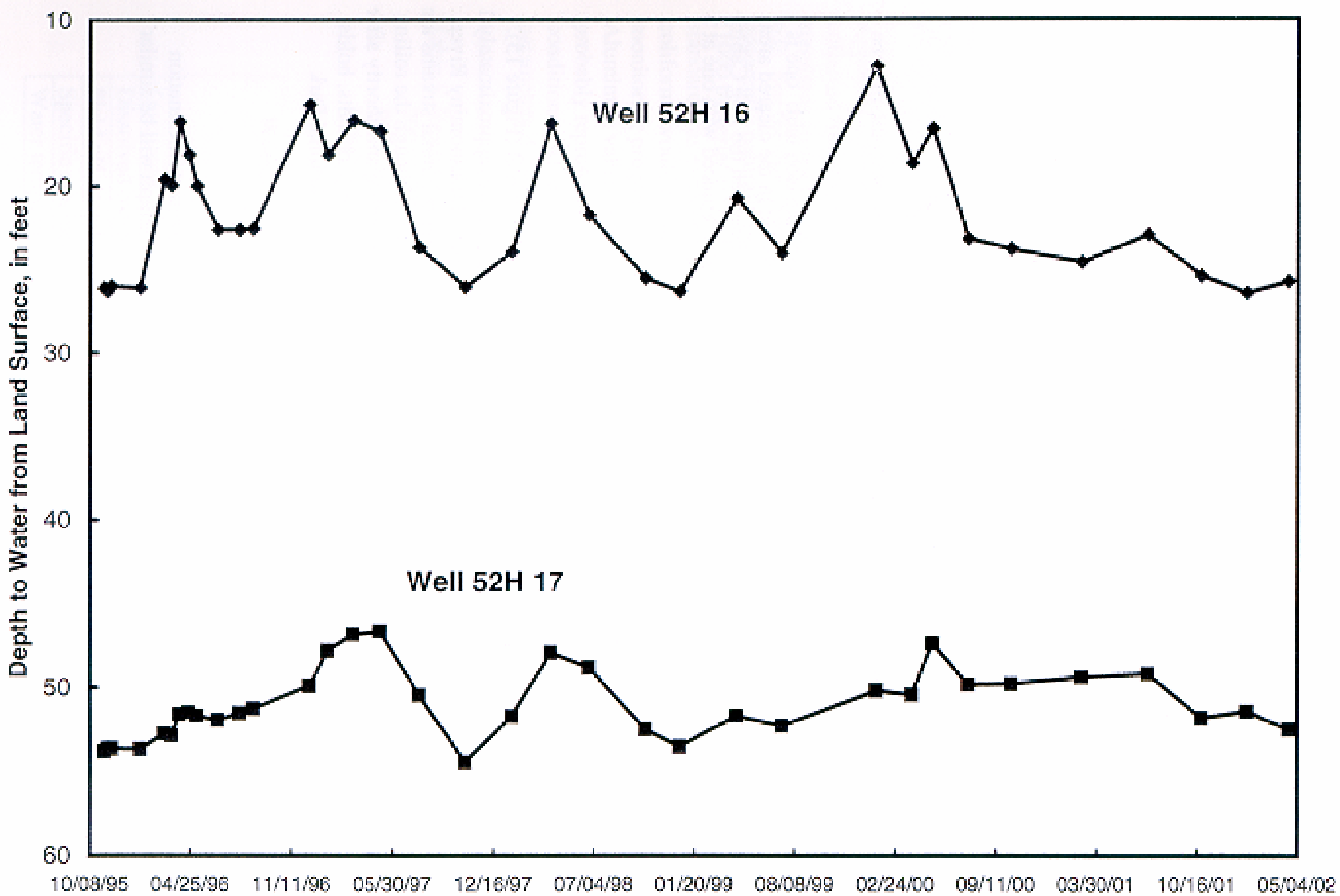

Figure 19. Water-level measurements in wells at the Fort Harrison unit, 1995-2002.

Water Supply and Sewage Disposal

Five wells in the Fort Harrison unit are used for water supply: one for the two houses on Maintenance Way, one for the Maintenance Yard, and three for the Visitor Center and Log Cabin (James Hedge, Richmond NBP, pers. comm. 2002).

There is a pump house south of the Log Cabin that filters, chlorinates, and creates pressure for water that supplies the Visitor Center and Log Cabin. One of the three wells supplying the pump house is presumably a pre-1950 well with unknown depth. The water reportedly has very high iron and was treated with a filtration-ion exchange-chlorination system (Sharrow, no date). There was a total coliform problem in 1991, which was reportedly the result of inadequate flushing of a new pipeline and was corrected (Sharrow, no date).

A 28,000-gallon water tank exists on Maintenance Way across from the two houses. In the past, the tank was used to store water from the wells to be supplied to the pump house, however, the storage tank has been taken off line. In the future, the tank may be used for fire suppression.

There are three septic tanks and associated leach fields in the Fort Harrison unit: one is located in the bone yard behind the Maintenance Yard, one is located in the cleared area adjacent to the Ranger Office, and the third is in the cleared area between the Log Cabin and the adjacent earthwork. One of the leach fields failed and was replaced with one at a new location in 1990 (Sharrow, no date).

GAINES' MILL

Watershed Description

Boatswain Creek forms the northwestern boundary of the Gaines' Mill unit (Figure 15). The headwaters of Boatswain Creek originate near the Garthright House, approximately 1 mile upstream of the Gaines' Mill unit. Boatswain Creek joins the Chickahominy River approximately 0.8 mile southeast of the Gaines' Mill unit. No other perennial streams are shown within the unit on the USGS 1:24,000-scale topographic map, although the rolling topography suggests that ephemeral tributaries and wetlands exist during and shortly after storms. The Cretaceous-aged Patuxent Formation, which underlies the park units, holds "a significant amount of water" in the 100- to 300-foot thick aquifer (National Park Service 1996).

Surface-Water Resources

No stream-gaging stations exist within the Gaines' Mill unit, so no direct information about surface-water quantity is available. The surface-water hydrograph will be similar in shape to that shown in Figure 12, as described above.

No wastewater dischargers, drinking-water intakes, water gages, or impoundments are located within the current boundaries of the Gaines' Mill unit (National Park Service 1999).

In 1987, the National Park Service performed water testing for the parasitic amoeba *Naegleria fowleri* within the unit, but none were found (documents on file at Richmond NBP).

In 1996, temperature, pH, dissolved oxygen, specific conductance, redox potential, and hardness were determined (data sheets on file at Richmond NBP).

According to the STORET data in the Baseline report (National Park Service 1999), no surface-water quality monitoring stations are located within the current boundaries of the unit. However, with the implementation of the Level I WAQIM, two water quality stations were established on Boatswain Creek – one each at the eastern and western boundaries. Sampling occurred quarterly from August 2001 to April 2002. See Appendix C for the results of this sampling. Table 9 summarizes the water quality data collected from the Gaines' Mill unit during the Level I WAQIM. No State water quality standards were exceeded except pH values were consistently below the State standard of 6.0. See the discussion under BEAVER DAM CREEK for an explanation of these apparently naturally occurring acidic conditions. The State standard for fecal coliform (1000 bacteria/ 100 mL) was exceeded once and this represents the only time that this standard was exceeded at any unit. This suggests that the measurement of fecal coliforms would be an infrequent water quality monitoring parameter in any future monitoring program, especially given that waters in the park are non-recreational waters. Aluminum values were elevated and similar to those at the Cold Harbor unit. This probably represents some mobilization of aluminum from the sediments under low pH conditions. All other water quality results are unremarkable. This suite of water quality parameters does not indicate a strong influence from surrounding land use.

Table 9. Results of surface-water samples collected in the Gaines' Mill unit during the 2001-2002 Level I WAQIM. Not all water quality parameter results are shown. Refer to Appendix C for complete water quality parameter results and sample locations.

Water-Quality Parameter, unit	**Boatswain Creek East Range, Sample Size**	**Boatswain Creek West Range, Sample Size**
Discharge, ft^3/s	0.07-0.5, n=4	---
Dissolved oxygen, mg/L	7.6-11.6, n=4	4.0-11.4, n=4
Field pH, standard units	5.4-6.5, n=4	5.3-6.2, n=4
Specific conductance, µS/cm	52-59, n=4	57-67, n=4
Water temperature, ºC	5.7-23. n=4	5.2-21.3, n=4

Alkalinity, mg/L as $CaCO_3$	3-9, n=4	3-9, n=4
Ammonia, mg/L as NH_4	0.037-0.136, n=4	0.05-0.131, n=4
Total phosphorus, mg/L	0.01-0.042, n=4	0.013-0.073, n=4
Fecal coliform, col./100 mL	16-200, n=4	29-1200, n=4
Dissolved calcium, mg/L	0.96, n=1	1.79, n=1
Dissolved magnesium, mg/L	1.39, n=1	1.79, n=1
Dissolved potassium, mg/L	1.06, n=1	2.38, n=1
Dissolved sodium, mg/L	3.8, n=1	4.8, n=1
Unfiltered acid neutralizing capacity, mg/L as $CaCO_3$	7, n=1	9, n=1
Dissolved chloride, mg/L	7.2, n=1	9.8, n=1
Dissolved fluoride, mg/L	<0.1, n=1	<0.1, n=1
Dissolved silica, mg/L	4.2, n=1	2.3, n=1
Dissolved sulfate, mg/L	1.8, n=1	2.5, n=1
Aluminum, µg/L	157, n=1	217, n=1
Dissolved iron, µg/L	810, n=1	1690, n=1
Lead, µg/L	present, n=1	present, n=1
Dissolved manganese, µg/L	15, n=1	56, n=1

[n=, number of samples; °C, degrees Celsius; ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; NH_4, ammonium; µg/L, micrograms per liter; col., colonies; --, no data]

Ground-Water Resources

A National Park Service employee inhabits the Watt House in the Gaines' Mill unit. The well used for water supply at the Watt House is referred to as well 142-072, according to the well-numbering system of the Virginia DEQ. The well was drilled in 1962 to a depth of 199 feet, with a 4-inch diameter well casing, and a screened interval of 180 - 190 feet below land surface (David Nelms, USGS, pers. comm. 2000). Ground-water level data are not available from this well. Because of the proximity of the Gaines' Mill unit to the Cold Harbor unit and the similarity of the well depths, however, water levels of deep ground water likely are similar in both units.

According to USGS records, a water-quality sample was collected from well 142-072 on 1 December 1972 (Table 10).

A spring (52HS 1) located in eastern Henrico County approximately 6 miles south of the Gaines' Mill unit was sampled on October 28, 1998 by the USGS (White and Powell 2000). Springs in the Coastal Plain of Virginia typically are indicative of shallow ground water. The shallow ground water supplies most of the water to the headwater streams and wetlands and thus determines the quality of the aquatic habitat in those locations.

Table 10. Comparison of results of deep and shallow ground-water samples collected in and near the Cold Harbor and Gaines' Mill units.

Water-Quality Parameter, and Unit of Measurement	Gaines' Mill well	Cold Harbor well	Spring
Identification number	142-072	52J 10	52HS 1
Sample date	12/1/72	8/30/84	10/28/98
Water temperature, °C	--	20	16
Specific conductance, µS/cm	275	230	66
pH, units	7.9	7.4	4.4
Oxygen, mg/L	--	0.7 (8% sat.)	3.9 (40% sat.)
Bicarbonate, mg/L	140	--	0.0
Carbonate, mg/L	113	102	0.0
Nitrogen, (NO_2 + NO_3), mg/L	--	0.17	2.9
Total hardness, mg/L as $CaCO_3$	65	63	--
Calcium, mg/L	18	17	--
Magnesium, mg/L	4.9	5.1	--
Sodium, mg/L	25	12	--
Potassium, mg/L	13	15	--
Chloride, mg/L	1.9	1.8	--
Sulfate, mg/L	15	7.3	--
Fluoride, mg/L	0.4	0.1	--
Silica, mg/L	14	13	--

[All concentrations are dissolved, unless otherwise noted; --, no data; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; sat., saturation; NO_2 + NO_3, nitrite plus nitrate; $CaCO_3$, calcium carbonate; µg/L, micrograms per liter]

For the purpose of comparison, results of the water-quality sampling of the wells at the Cold Harbor and Gaines' Mill units (representing deep ground water) and the spring (representing shallow ground water) are shown in Table 10. A comparison of these data demonstrates the differences in ground-water quality that result from differences in flow paths. In general, water emanating from a spring has followed relatively short and shallow flow paths and has had a short residence time below land surface, resulting in relatively low dissolved solids concentrations and lower specific conductance. In contrast, deep ground water, such as that sampled in the wells, has followed longer, deeper flow paths and has longer residence times below land surface; this longer contact time with geologic materials increases the dissolved solids of the water. For example, the deep ground water in the wells had specific conductance measurements in excess of 200 µS/cm (indicating a longer contact time), in contrast to shallow water from the spring, which had a specific conductance of 66 µS/cm (indicating a shorter contact time) (Table

10). Also evident from the ground-water data (Table 10) is the similarity of the quality of the deep ground-water samples that were collected more than a decade apart. This may indicate that the water sampled was from the same aquifer and that the water quality had changed little over time. Ground water with short, shallow flow paths tends to be more susceptible to contamination from the ground surface than deep ground water. For example, the higher nitrogen concentration at the spring suggests that the shallow water might be influenced by nearby agricultural activities and fertilizer application. For reasons like this, potable water supplies typically are obtained from deep confined aquifers, such as the well used for water supply at the Cold Harbor Visitor's Center before the switch to county water. This comparison of deep and shallow ground-water quality demonstrates the difference in water chemistry between the two depths of ground water and emphasizes the importance of maintaining the quality of shallow ground water.

Wetland and Riparian Resources

Only one wetland is delineated on the NWI map (Seven Pines) for the Gaines' Mill unit, along Boatswain Creek. The mapped wetland is described as a seasonally flooded, broad-leaved deciduous palustrine wetland. Palustrine wetlands are the dominant type of wetland (100%) because of the forest cover in the Gaines' Mill unit. Palustrine wetlands are non-tidal and dominated by trees, shrubs, persistent emergent vegetation and emergent mosses or lichens (Cowardin *et al.* 1979). Broad-leaved deciduous refers to dominant trees such red maple (*Acer rubrum*), American elm (*Ulmus americana*), and ashes (*Fraxius* spp.), among others. Seasonally flooded refers to wetlands in which surface water is present for extended periods especially early in the growing season, but is absent by the end of the growing season in most years.

Water Supply and Sewage Disposal

Well 142-072, drilled in 1962, was used for private water supply to the Watt House until early 2000. Because of a cracked casing, the well was abandoned, and a new well was installed in February 2000 (Jerry Helton, Richmond NBP, pers. comm. 2000). The replacement well is 325 feet deep, has 4.5 inch-diameter casing, a screened interval from 295 to 325 feet, and a yield of 15 gallons per minute after 4 hours of pumping (David McKinny, Richmond NBP, pers. comm. 2000).

The septic system in use at the Watt House was installed in 1957 (drawings on file at Richmond NBP). Currently, the system appears to be functioning properly (David McKinney, Richmond NBP, pers. comm. 2000).

MALVERN HILL/GLENDALE

Watershed Description

The Malvern Hill and Glendale units contain several tributaries of Turkey Island Creek, within the James River watershed. Crewes Channel drains a wetland area referred to as The Slash, which lies directly northwest of the unit. It runs through the park for a distance of approximately one mile and empties into Turkey Island Creek approximately 1.5 miles downstream. Four unnamed tributaries join McDowell Creek (for which the headwaters lie approximately one mile north of the unit) within the northern section of the unit (Figure 20). McDowell Creek then joins Western Run (starting approximately 0.5 mile northwest of the unit) within the unit, running through the park for a combined distance of approximately 1.3 miles. Western Run empties into Turkey Island Creek approximately one mile south of the unit. Turkey Island Creek then drains into the James River. This watershed consists primarily of forest, agriculture and rural residential development areas (single family residences with at least one-acre lot sizes). Although these tributaries are surrounded by forest along much of their lengths, Crewes Channel runs directly adjacent to four agricultural fields, typically farmed for winter wheat and soybean. These fields are often visited by flocks of Canadian Geese in the fall and winter when the fields are plowed, possibly degrading water quality.

Surface-Water Resources

Three perennial streams flow within the unit: Western Run, McDowell Creek, and Crewes Channel. These streams flow into Turkey Island Creek, which flows southward to the James River.

No stream-gaging stations exist within the Malvern Hill/Glendale units, so no direct information about surface-water quantity is available. The surface-water hydrograph will be similar in shape to that shown in Figure 12, as described above.

According to the STORET data in the Baseline report (National Park Service 1999), no surface-water quality monitoring stations are located within the current boundaries of the unit. However, with the implementation of the Level I WAQIM four water quality stations were established – one on an unnamed tributary, one on Western Run, and two on Crewes Channel. Sampling occurred quarterly from August 2001 to April 2002. See Appendix C for the results of this sampling. Table 11 summarizes the water quality data collected from the Malvern Hill/Glendale unit during the Level I WAQIM. No State water quality standards were exceeded except pH and dissolved oxygen. On Crewes Channel the State pH standard (6.0) was exceeded seven out of eight times. These low pH values are probably a result of the fact that this stream drains a wetland area and the stream has naturally low alkalinity and acid neutralizing capacity. Dissolved oxygen levels exceeded the State standard (4.0 mg/L) three out of 12 samples over the four stations. These low values were associated with no-to-little flow and represent stagnant conditions. Three out of four stations showed dissolved ammonia spikes during the April 2002 sampling. While these values do not exceed the suggested EPA criterion of 2.0 mg/L, they suggest a possible connection between upstream land use and spring runoff. Total dissolved phosphorus values in Crewes Channel were the highest of any sampled unit and exceeded the EPA suggested criterion of 0.1 mg/L in five out of eight samples. These values also suggest the possibility of land use impacts – perhaps fertilizer application to the upstream agricultural fields. Higher aluminum, lead, and manganese values may represent mobilization of these metals under acidic conditions and/or land use impacts. Any future water-quality monitoring program in the park should include the

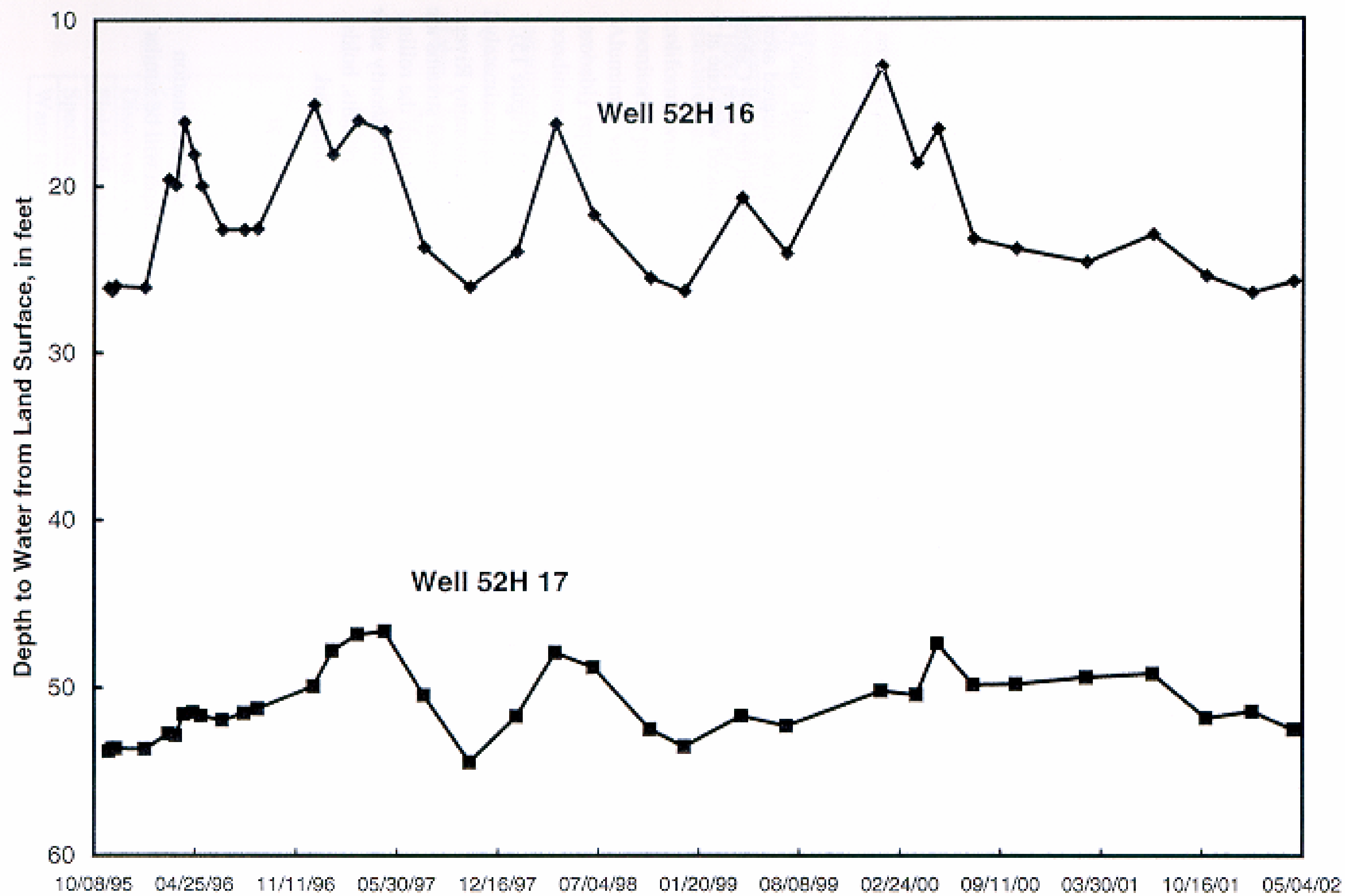

Figure 19. Water-level measurements in wells at the Fort Harrison unit, 1995-2002.

measurement of total phosphorus and, for Crewes Channel in particular, lead and manganese.

Ground-Water Resources

Ground-water resources have not been developed at this unit. The wetland areas likely serve as ground-water discharge zones to Western Run, McDowell Creek, and Crewes Channel.

Table 11. Results of surface-water samples collected in the Malvern Hill/Glendale unit during the 2001-2002 Level I WAQIM. Not all water quality parameter results are shown. Refer to Appendix C for complete water quality parameter results and site locations.

Water-Quality Parameter, unit	Unnamed tributary	Crewes Channel Upstream	Crewes Channel Downstream	Western Run
Discharge, ft^3/s	0.08-0.14, n=2	0.0, n=2	---	2.2, n=1
Dissolved oxygen, mg/L	3.6-9.3, n=4	2.2-20.5, n=4	3.3-8.6, n=4	6.4-11.6, n=4
Field pH, standard units	5.3-6.6, n=4	4.9-5.7, n=4	5.6-6.5, n=4	5.5-6.4 =4
Specific conductance, µS/cm	58-96, n=4	52-80, n=4	94-149, n=4	56-70, n=4
Water temperature, ºC	8.8-19.2, n=4	6.2-22.1, n=4	5.7-25.8, n=4	3.2-23.3, n=4
Alkalinity, mg/L as $CaCO_3$	12-17, n=4	2-11, n=4	26-33, n=4	12-17, n=4
Dissolved ammonia, mg/L as NH_4	0.026-0.428, n=4	0.027-0.9, n=4	0.04-1.75, n=4	0.04-0.112, n=4
Total phosphorus, mg/L	0.006-0.055, n=4	0.025-0.585, n=4	0.174-0.454, n=4	<0.004-0.063, n=4
Fecal coliform, col./100 mL	8-160, n=4	21-700, n=4	39-190, n=4	20-740, n=4
Dissolved calcium, mg/L	5.58, n=1	2.51, n=1	10.2, n=1	5.7, n=1
Dissolved magnesium, mg/L	0.567, n=1	1.2, n=1	2.13, n=1	1.25, n=1
Dissolved potassium, mg/L	1.23, n=1	5.75, n=1	1.81, n=1	2.97, n=1
Dissolved sodium, mg/L	3.6, n=1	3.6, n=1	4.9, n=1	3.9, n=1
Acid neutralizing	17, n=1	27, n=1	28, n=1	19, n=1

capacity, mg/L as $CaCO_3$				
Dissolved chloride, mg/L	7.1, n=1	9.3, n=1	9.7, n=1	8.7, n=1
Dissolved fluoride, mg/L	<0.1, n=1	<0.1, n=1	<0.1, n=1	0.1, n=1
Dissolved silica, mg/L	13, n=1	1.1, n=1	0.1, n=1	7.9, n=1
Dissolved sulfate, mg/L	0.8, n=1	1.7, n=1	2.3, n=1	0.9, n=1
Aluminum, µg/L	48, n=1	1170, n=1	700, n=1	49, n=1
Dissolved iron, µg/L	270, n=1	4240, n=1	3020, n=1	2550, n=1
Total lead, µg/L	<1, n=1	8, n=1	5, n=1	<1, n=1
Dissolved manganese, µg/L	32, n=1	1500, n=1	1270, n=1	91, n=1
Total mercury, µg/L	<0.01, n=1	0.02, n=1	<0.01, n=1	<0.01, n=1

[n=, number of samples; ft^3/s, cubic feet per sec; col., colonies; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; NH_4, ammonium; µg/L, micrograms per liter; --, no data]

Wetland and Riparian Resources

The Malvern Hill and Glendale units contain approximately 30 acres of wetland associated with Crewes Channel and approximately 62 acres associated with the McDowell Creek/Western Run watershed. The wetlands associated with Crewes Channel are classified as palustrine and some areas may have been modified by past drainage/ditching for adjacent agriculture. Palustrine wetlands are non-tidal and dominated by trees, shrubs, persistent emergent vegetation and emergent mosses or lichens (Cowardin *et al.* 1979). Throughout the majority of these wetlands, the soils are classified as seasonally flooded/saturated, however, the southernmost portion is semi-permanently flooded. Seasonally flooded refers to wetlands in which surface water is present for extended periods during the growing season, but can be absent by the end of the summer. The southernmost portion of the wetland is composed of persistent emergents, however, upstream community types consist of broad-leaved deciduous shrubs followed by broad-leaved deciduous forest. The wetlands associated with the McDowell Creek and Western Run watersheds are classified as palustrine and primarily seasonally flooded/saturated. The majority of this wetland is inhabited by broad-leaved deciduous forest.

Water Supply and Sewage Disposal

No such infrastructure exists at this unit.

HOLISTIC WATERSHED MANAGEMENT

The following text is excerpted from a book by Doppelt *et al.* (1993) entitled "Entering the Watershed, A New Approach to Save America's River Ecosystems." It is intended as a brief primer on the importance of a holistic, watershed context to understanding the structure and function of stream ecosystems and the responses of stream ecosystems to perturbations. Combined with what is currently known of the park's stream ecosystems, it sets the stage for future stream management within park boundaries.

> "In the past 15 years many scientific studies and reports have documented that riverine systems are intimately coupled with and created by the characteristics of their catchment basins or watersheds. Watersheds involve four-dimensional processes that connect the longitudinal (upstream-downstream), lateral (floodplains-upland), and vertical (hyporheic or ground water zone-stream channel) dimensions, each differing temporally.
>
> Watersheds are ecosystems composed of a mosaic of different land or terrestrial patches that are connected by a network of streams. In turn the flowing water environment is composed of a mosaic of habitats in which organisms, materials and energy move in complex, yet highly integrated, systems. Physical and chemical processes and complex food webs depend on these movements. Given the dynamic connectedness of a watershed, management activities can fragment and disconnect the habitat patches if they are not planned and implemented from an ecosystem and watershed perspective.
>
> Processes that occur within the watershed, therefore, largely determine in-stream conditions, and they cannot be isolated from or manipulated independently of this context. A riverine system is an open ecosystem because a large proportion of the materials and energy in the system are derived from the surrounding terrestrial system, yet flow outward. Disturbances in a watershed propagate downstream from headwater sources. The protection of sensitive headwater areas in watersheds is therefore critical to maintaining and restoring riverine habitat and ecosystems for considerable distances downstream.
>
> Flowing freshwater systems are directly linked with the terrestrial environment—the land base—for shade and input of nutrients and organic materials. The riparian area is the area where that interface occurs. The riparian area is linked with the flowing water ecosystem to such an extent that the former is the essential part of the latter. Thus, the term riverine-riparian ecosystem more accurately describes the entire area (National Research Council 1992).
>
> When described alone, the riparian area means an ecotone (transition region) between flowing water and terrestrial ecosystems, which serves as the area of continuous exchange of nutrients and woody debris between land and water (Skovlin 1984). Riparian vegetation is an especially critical component of the watershed, because it provides an estimated 90 percent of the in-stream nutrients

in the aquatic food web (Platts 1981). Although riparian areas constitute a relatively small proportion of the nation's land area, they are of vital importance to the ecological and biological health of watershed ecosystems.

Riparian vegetation provides shade, helping to maintain water temperatures at the levels to which native riverine-riparian biodiversity are best adapted. Leaves and woody debris from the riparian area feed the water with nutrients for growth of aquatic plants and provide food and habitat for the insects upon which fish feed. This debris also contributes to the physical structure of the system by slowing water velocity and deflecting its course. As the water is slowed and deflected, it pushes against the banks and into the soils underlying the adjacent floodplain, thereby contributing to the local water table. Riparian areas are a vital source of important structural components of the entire riverine system.

Healthy riverine systems are dynamic, changing systems that tend to meander. Their movement contributes to the health of the ecosystem because it slows water velocity in flood stages, burying and storing organic materials upon which certain species depend, while releasing the degraded materials that are crucial to the survival of other species. It creates a complete mosaic of seasonal habitats for riverine-riparian biodiversity. The dynamic nature of the systems is an important consideration in any restoration approach—the system's ability to move and change must be protected.

Riverine-riparian ecosystems play an important role in producing habitats for both terrestrial and riverine biodiversity. Riverine habitats support the greatest biodiversity of any aquatic habitat types, including lakes and springs. Riverine-riparian ecosystems provide life-supporting habitat for multitudes of non-fish vertebrate and invertebrate species—key links in the aquatic food chain. They are also natural highways for migratory birds and other forms of biodiversity. The biological diversity supported by riverine-riparian ecosystems is a critical link in the entire natural food chain of which human beings are a part.

Human activities continue to degrade America's riverine systems and biodiversity in a variety of ways. The cumulative result of the many impacts has been called ecosystem simplification: huge reductions in the life-supporting complexity and diversity of riverine ecosystems. As complexity is reduced, the system's ability to repair itself after natural and human-caused disturbances erodes, leaving many systems and species seriously harmed or extinct, and with reduced ability to perform ecological functions. The most damaging impacts usually result from changes to the basic structure and function of riverine-riparian ecosystems and habitats.

Riverine ecosystem simplification is caused by a number of factors including: 1) changes in water quantity or flow; 2) modification of channel and riparian ecosystem morphology through dams, channelization, and drainage and filling of wetlands; 3) damaging land use practices; 4) degrading water quality through addition of point- and nonpoint-source contaminants; 5) the decline of native fish and other species from overharvest and intentional or accidental poisoning; and 6) the introduction of exotic species (Karr 1991). These activities may occur anywhere within the watershed, along the riparian or floodplain areas, or in river channels.

Ecosystem simplification is the cumulative result of these impacts. It is the dramatic reduction of the complexity and diversity of structure, function and biological factors of riverine systems (Allen and Flecker 1993). This leaves the ecosystems, habitats and species unable to withstand disturbances, both natural and human-induced, and ultimately unable to perform ecological functions or to repair themselves."

WATER-RESOURCES PLANNING ISSUES AND RECOMMENDATIONS

Representatives of the National Park Service-Water Resources Division (WRD) and National Park Service-Northeast Region Philadelphia Support Office traveled to Virginia in August 1999 to meet with representatives from the Richmond NBP, the U.S. Geological Survey (USGS), and the National Park Service-Chesapeake Bay Program Coordinator. This meeting was designed to allow participants to gain familiarity with the park's water-resource features and to initiate dialogue on park water-resource issues and management concerns. Initial discussions indicated that there is a lack of baseline water-quality and quantity data for the park and that urbanization is encroaching on the boundaries of the park. Additional water-resources issues were identified at scoping sessions with WRD, Richmond NBP, and USGS personnel on January 27, 2000 and October 24-25, 2000 at Richmond NBP (Appendix D). Subsequent discussions have been held with additional NPS personnel, and federal, state, and county officials, in order to further refine potential water-resources issues and develop possible solutions for these issues. As a result of these meetings and discussions, the following information deficiencies were identified:

1) Lack of adequate current water-quality data and supporting information to assess potential water-quality degradation from nonpoint-source pollution, as related to changing land use;

2) Lack of data and supporting information on wetland and riparian resources; and

3) Lack of an adequate inventory of aquatic-dependent flora and fauna.

In addition, as a result of conducting research for this Water Resources Management Plan, two other issues—the need to identify and control invasive exotic species, and the need to adopt a proactive culture to protect park lands—were identified. All of these issues are discussed below.

ADEQUACY OF CURRENT WATER-QUALITY INFORMATION TO ASSESS POTENTIAL WATER-QUALITY DEGRADATION FROM NONPOINT-SOURCE POLLUTION, AS RELATED TO CHANGING LAND USE

It appears that the quality of water in general is good within the headwater streams flowing through the park units. Nonpoint-source pollutants associated with increasing residential development, however, could adversely affect existing water quality. Contamination could derive from such nonpoint sources as subdivision development, runoff associated with agriculture and developed areas, septic system leachate, and lawn and garden chemicals. Residential development often results in the reduction of infiltration areas by creating impervious surfaces, which can increase storm-water runoff and alter discharge and hydrologic patterns of streams. This, in turn, may lead to additional sediment loading and channel scour in the receiving stream. Improperly designed slopes or poor construction practices also can increase surface erosion and sediment load. For example, developments adjacent to the Beaver Dam Creek unit increased sediment deposition to Beaver Dam Creek within the unit. Many of the residences surrounding the park units have expansive lawn areas, which undoubtedly receive applications of fertilizers and pesticides. Little information is currently available regarding the types and amounts of chemicals applied or the potential for runoff of these chemicals into adjacent streams. Point- and nonpoint-source pollutants in residential areas, however, generally are plentiful and easily transported over impervious surfaces, directly into watercourses and tributaries. Therefore, present and expected development in the watersheds upstream of the park units has the potential to impair surface- and ground-water quality, alter the surface- and ground-water hydrographs, and negatively affect biological resources in the units.

The paucity of specific information on surface-water features (wetlands and riparian areas), surface- and ground-water quantity and quality, and aquatic biology compromises the direction of water-resources planning. Without better water-resource information and adequate baseline data, any impacts on water resources will remain undetected and changes will be difficult to document. However, a comprehensive water-quality-monitoring program for surface and ground waters is not warranted given that the streams are small and drain headwater watersheds – impacts from adjacent land use are immediate and there is little area to cause cumulative impacts from upstream land use. Additionally, at present, park financial and staff limitations would not sustain a long-term comprehensive monitoring program with adequate quality assurance and control. What is needed is a sustainable, scientifically credible, ‘canary-in-the-mine’ monitoring program that is efficient, cost-effective, and provides a warning of resource degradation. This type of monitoring program does not need to be conducted on a frequent basis. If the program determines that a water-resource problem exists, then more intensive study plan can be developed to determine the exact nature and cause of the problem.

A systematic, biological assessment of species assemblages using multimetric indexes to assess biological integrity is currently a very practical and cost-effective approach to determine if human actions are degrading water resources. The phrase “biological integrity” was first used in 1972 to establish the goal of the Clean Water Act: "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." This mandate clearly established a legal foundation for protecting aquatic biota. The vision of biological integrity, however, was not reflected in the act's regulations for implementation. Those regulations were aimed at controlling or reducing release of chemical contaminants and thereby protecting human health; the integrity of biological communities was largely ignored (Karr 1991). The health of aquatic organisms and the quality of aquatic environments have declined in recent decades, possibly as a result. Any assessment of water resources extends beyond degradation of water quality as a result of pollutants, because of the subsequent potential loss of aquatic species and homogenized biological assemblages.

Biological integrity refers to the capacity to support and maintain a balanced, integrated, and adaptive biological system having the full range of elements (e.g. populations, species, assemblages) and processes (e.g. biotic interactions, energy dynamics, biogeochemical cycles) expected in a region's natural habitat (Karr *et al.* 1986). The biological integrity of water resources is jeopardized by altering one or more of five classes of environmental factors: physical habitat, seasonal flow of water, the food base of the system, interactions within the stream biota, and chemical contamination (Karr 1992). Urbanization, for example, compromises the biological integrity of streams by severing the connections among segments of a watershed and by altering hydrology, water quality, energy sources, habitat structure, and biotic interactions (e.g. Figure 3).

Water managers are increasingly being called upon to evaluate the biological effects of their management decisions. No other aspect of a river gives a more integrated perspective on its health than the condition of its biota. Widespread recognition of this and the continued degradation of our water resources have stimulated numerous efforts to improve our ability to track aquatic biological integrity (Davis and Simon 1995). Comprehensive, multimetric indexes (Barbour *et al.* 1995) were first developed in the Midwest for use with fishes (Karr 1981; Fausch *et al.* 1984; Karr *et al.* 1986), and modified for use in other regions of the U. S. (Miller *et al.* 1988) and with invertebrates (Ohio EPA 1988; Plafkin *et al.* 1989; Kerans and Karr 1994; Deshon 1995; Fore *et al.* 1996). The conceptual basis of the multimetric approach has now been applied to a variety of aquatic environments (Davis and Simon 1995), including large rivers, lakes, estuaries, wetlands, riparian corridors, and reservoirs, and in a variety of geographic locations (Lyons *et al.* 1995).

Comprehensive approaches have been developed and are being adopted by state and federal agencies. Forty-two states (including Virginia) now use multimetric biological assessments of biological condition and six states are developing biological assessment approaches; only three states used multimetric biological approaches in 1989 (U.S. Environmental Protection Agency 1996a). Only over the last few years have efforts been made to monitor the biological integrity of water resources, as mandated by the Clean Water Act 28 years ago (Karr 1991; Davis and Simon 1995; U.S. Environmental Protection Agency 1996a,b).

The set of metrics incorporated into a multimetric index integrates information from ecosystem, community, population, and individual levels (Karr 1991; Barbour *et al.* 1995).

Multimetric indexes are generally dominated by metrics of taxa richness (number of taxa), because structural changes, such as shifts among taxa, generally occur at lower levels of stress than do changes in ecosystem processes (Karr *et al.* 1986; Schindler 1987, 1990). However, the most appropriate and integrative multimetric indexes embrace several components, such as taxa richness, indicator taxa or guilds (e.g. tolerant and intolerant), health of individual organisms, and assessment of processes (e.g. as reflected by trophic structure) of the sampled assemblage.

Like the multimetric indexes used to track national economies, multimetric biological indexes measure many dimensions of complex ecological systems (Karr 1992). Multimetric economic indexes assess economic health against a standard fiscal period; indexes of biological integrity assess the biological well being of sites against a regional "baseline condition" reflecting the relative absence of human influence. The goal is to understand and isolate, through sampling design and analytical procedures, patterns that derive from natural variation in environments.

Biological assessments using multimetric indexes provide both numeric and narrative descriptions of resource condition, which can be compared among watersheds, across a single watershed, and over time (Karr 1991), and they do so at costs that are often less than the cost of complex chemical monitoring. Costs per evaluation are relatively low for ambient biological monitoring. Based on a decade of sampling and including equipment; supplies; and logistical, administrative, and data-analysis and interpretation activities, benthic invertebrates cost $824/sample and fish cost $740/sample (Yoder and Rankin 1995) in comparison with chemical and physical water quality ($1,653 per station) and bioassays ($3,573 to $18,318 per assay).

The Index of Biotic Integrity (IBI; Karr 1981), the first of the multimetric indexes and centered on fish communities, was conceived to provide a broadly based and ecologically sound tool to evaluate biological conditions in midwestern streams. The IBI and other, similar indexes are based on a series of assumptions and intuitions of how biotic assemblages change with increased environmental degradation. A single sample from a stream reach is evaluated using 12 metrics to compare the divergence of the resident biotic community from that expected of an undisturbed site in the same geographic area and of the same stream size (Table 12). Unlike efforts to define chemical criteria that do not take into account variation by geographic region, this approach explicitly recognizes natural variation in water-resource conditions. Ratings are assigned, summed, and placed into integrity classes (excellent, good, fair, poor, and very poor) to provide an assessment of the biological integrity or health of a system.

The 12 metrics represent differing sensitivities across the range of biotic integrity. Municipal effluents, for example, generally affect total abundance and trophic structure. Toxic effects are typically manifested as unusually low total abundance. Some environments low in nutrients also can support a limited number of individuals; an increase in abundance could indicate organic enrichment. Additionally, bottom-dwelling species that depend on benthic habitats are especially sensitive to siltation and oxygen depletion and are good barometers of habitat degradation.

Table 12. Typical effects of environmental degradation on biotic assemblages (from Fausch *et al.*1990).

1. The number of native species, and those in specialized taxa or guilds declines
2. The percentage of exotic or introduced species or stocks increases
3. The number of generally intolerant or sensitive species declines
4. The percentage of the assemblage comprising tolerant or insensitive species increases
5. The percentage of trophic and habitat specialists declines
6. The percentage of trophic and habitat generalists increases
7. The abundance of the total number of individuals declines
8. The incidence of disease and anomalies increases
9. The percentage of large, mature, or old-growth individuals declines
10. Reproduction of generally sensitive species declines
11. The number of size- and age-classes declines
12. Spatial or temporal fluctuations are more pronounced

Regardless of whether fish, invertebrates, or other taxa are used, the search for a small set of metrics that reliably signals resource condition along gradients of human influence yields the same basic list of metrics (Miller *et al.* 1988; Karr 1991; Davis and Simon 1995). With usually only minor modification, the list can be adapted to specific regions (Miller *et al.* 1988).

In Virginia, the 1998 Biological Monitoring Program of the Virginia DEQ uses the study of bottom-dwelling macroinvertebrate communities to determine overall water quality. This monitoring program is composed of stations examined twice annually, during the spring and fall. The U.S. EPA's Rapid Bioassessment Protocol II (Plafkin *et al.* 1989; Table 13) has been employed since the fall of 1990 as a standardized and repeatable methodology. The results of this protocol produce water-quality ratings of nonimpaired, moderately impaired, and severely impaired.

The procedure evaluates the macroinvertebrate community by comparing ambient monitoring network stations to reference sites. A reference site is one that has been

Table 13. Criteria[a] for the characterization of biological condition for Rapid Bioassessment Protocol II (after Plafkin *et al.* 1989).

Metric	Biological Condition: Non-Impaired	Biological Condition: Moderately Impaired	Biological Condition: Severely Impaired
1. Taxa Richness	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.	Fewer taxa due to loss of most intolerant forms. Reduction in EPT taxa.	Few taxa present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.
2. Family Biotic Index (modified)			
3. Ratio of Scrapers/ Filtering Collectors[b]			
4. Ratio of EPT[c] and Chironomid Abundances			
5. % Contribution of Dominant Family			
6. EPT Index			
7. Community Similarity Index[d]			
8. Ratio of Shredders/Total[b]			

[a] Scoring criteria are generally based on percent comparability to a reference station.
[b] Determination of Functional Feeding Group is independent of taxonomic grouping.
[c] Three orders of aquatic insects (Ephemeroptera, Plecoptera, and Trichoptera) that are primarily intolerant of degraded conditions.
[d] Community Similarity Indices are used in comparison to a reference station.

judged to be representative of a natural, unimpaired waterbody. An additional product of this evaluation is a habitat assessment, which provides information on the comparability of each stream station to the reference site. Project Statement RICH-N-011.000 (Appendix A) proposes obtaining the services of the Virginia DEQ to conduct its Biological Monitoring Program on the streams in the park units. Because Program resources are currently limited, the project statement should be regarded as a template. For example, Dr. Greg Garman, Director of the Environmental Sciences Center of Virginia Commonwealth University, is a regional expert on the use of multimetric indexes to assess biological integrity in streams. If the services of the Virginia DEQ cannot be obtained within a reasonable time frame, the park is encouraged to seek the services of Dr. Garman or another consultant. Likewise, the Alliance for Chesapeake Bay (Diane Dunaway, Alliance for the Chesapeake Bay, pers. comm., 2000) has several appropriate outreach programs that could provide the labor force necessary to implement stream biological assessments through a partnership with the National Park Service. For example, the Alliance is beginning work to establish a Senior Environment Corps. The makeup of the Corps is commonly retired professionals (e.g. professors, federal/state agency employees). Contacting the Alliance would be a good first step in any attempt to remedy the paucity of biological information at the park.

WETLAND AND RIPARIAN RESOURCE MANAGEMENT

Riparian Resource Assessment

Physically, riparian areas help to control mass movements of materials and to determine channel morphology (Naiman and Decamps 1997). Material supplied to streams primarily comes from the uplands, as well as from erosion of stream banks, a process influenced by root strength and resilience. Stream banks largely devoid of riparian vegetation are often highly unstable and subject to mass wasting, which can widen channels by several to tens of feet annually. Major bank erosion is 30 times more prevalent on nonvegetated banks exposed to currents as on vegetated banks (Beeson and Doyle 1995). In addition, riparian areas provide woody debris to stream channels. Piles of woody debris dissipate water energy, trap moving materials, and create habitat (Naiman and Decamps 1997). Depending upon size, position in the channel, and geometry, woody debris can resist and redirect water currents, causing a mosaic of erosional and depositional patches in the riparian corridor (Montgomery *et al.* 1995).

Riparian forests exert strong controls on the microclimate of streams (Naiman and Decamps 1997). Stream water temperatures are highly correlated with riparian soil temperatures, and strong microclimatic gradients appear in air, soil, and surface temperatures, and in relative humidity.

Ecologically, riparian areas: 1) provide sources of nourishment—allochthonous inputs to rivers and herbivory; 2) control nonpoint sources of pollution, in particular, sediment and nutrients, in agricultural watersheds and in watersheds being developed; and 3) create, through variations in flood duration and frequency and concomitant changes in water-table depth and plant succession, a complex of shifting habitats at different spatio-temporal scales (Naiman and Decamps 1997).

Riparian habitats have evolved in a natural repeating cycle of flood and drought events. All floodplain vegetation, including riparian vegetation, therefore, is adapted to natural flood regimes. Species found on floodplains are present because they are better adapted to the conditions than nearby upland species. Five factors are critical in determining an individual plant's response to changes in water level: 1) the time of year during which flooding occurs; 2) flood duration; 3) water depth at time of flooding; 4) amount of siltation resulting from flood waters; and 5) flood frequency.

A delicate balance exists between the flora and fauna of riparian habitats and the annual flood regime. Unusually high summer flows may scour beds of aquatic vegetation, reducing cover for young-of-the-year fish, turtles, and invertebrates. Summer destruction of these plant beds also may affect waterfowl food supply and survival the following winter. Ill-timed high flows may destroy larvae of amphibians by flushing them from pools and backwaters. Ground-nesting birds in riparian habitats also may experience high mortality of nestlings.

The U.S. Bureau of Land Management has developed guidelines and procedures to rapidly assess whether a stream riparian area is functioning properly in terms of its hydrology, landform/soils, channel characteristics, and vegetation (Prichard *et al.* 1998). This assessment, commonly called Proper Functioning Condition (PFC), is useful as a baseline analysis of stream condition and physical function, and it can also be useful in watershed analysis.

PFC is a methodology for assessing the physical functioning of a riparian-wetland area. It provides information critical to determining the health of a riparian ecosystem. PFC considers both abiotic and biotic components as they relate to the physical functioning of riparian areas, but it does not consider the biotic component as it relates to habitat requirements. For habitat analysis, other techniques must be employed.

PFC is a useful tool for watershed analysis. Although the assessment is conducted on a stream-reach basis, the ratings can be aggregated and analyzed at the watershed scale. PFC, along with other watershed and habitat condition information, provides a good picture of watershed health and causal factors affecting watershed health.

Identifying streams and drainages where riparian areas along streams are not in proper functioning condition, and those at risk of losing function, is an important first step in the ultimate goal of restoration. Physical conditions in riparian zones are excellent indicators of what is happening in a stream or drainage above.

With the results of PFC analysis, it is possible to begin to determine stream corridor and watershed restoration needs and priorities. PFC results may also be used to identify where gathering more detailed information is needed and where additional data are not needed. The PFC inventory of riparian zones may be able to be used to identify those streams already impacted by stormwater flows.

PFC is not a quantitative field technique. An advantage of this approach is that it is less time consuming than other techniques because measurements are not required. The procedure is performed by an interdisciplinary team and involves completing a checklist evaluating 17 factors dealing with hydrology, vegetation, and erosional/depositional characteristics. Training in the technique is required, but the technique is not difficult to learn. While mainly developed in the arid West, it is considered to be applicable to riparian areas of the East (Joel Wagner, National Park Service, Water Resources Division, pers. comm. 1999). Park staff is urged to contact regional offices of the U.S. Forest Service, and the Natural Resources Conservation Service, and the U.S. Bureau of Land Management to discuss the applicability of PFC in the East. Project Statement

RICH-N-012.000 (Appendix A) is designed to assess riparian functional condition in all park units.

Enhanced Wetland Delineation

Richmond NBP has contracted with USGS to map the wetlands in the park. Aerial photography (orthophotoquads) at a scale of 1:12,000 were obtained from Henrico County for the Chickahominy Bluff, Beaver Dam Creek, Gaines' Mill, Malvern Hill, Drewry's Bluff, and Fort Harrison park units. Aerial photography (orthophotoquads) at a scale of 1:7,200 was produced, in March 2001, for the remaining park units: Parker's Battery, Cold Harbor, and the Garthright House. Site visits were conducted in November 2000. The orthophotoquads are in the process of being interpreted and wetlands mapped based on the Cowardin classification. Wetlands maps and classifications were due to Richmond NBP in the latter half of 2002.

ADEQUACY OF INVENTORY FOR AQUATIC-DEPENDENT FLORA AND FAUNA

To our knowledge, there have been no efforts to gather comprehensive data on any aspect of aquatic biology (e.g. fish, amphibians and reptiles, invertebrates, aquatic flora) in any of the park units. Potential funding by the Inventory and Monitoring program has recently become available to Richmond NBP to perform parkwide inventories of fish, amphibians, and reptiles. This current lack of documentation makes it impossible to detect changes or deterioration of the resources, determine the presence/absence of state and federally listed species, or detect the presence and potential impacts of exotic species. As succinctly stated in the RMP of Richmond NBP, "The available biological information is incomplete and inadequate to meet the full needs of the park (National Park Service 1994)". Examples of, and reasons for concern about, this lack knowledge for the park units are detailed in the following paragraphs.

The Virginia Department of Conservation and Recreation's Natural Heritage Program lists rare plants and animals by county. Some of these rare plants and animals also are on state and federal lists of concern. We checked these lists for Chesterfield, Hanover, and Henrico counties, which are available at < http://www.dcr.state.va.us/dnh/coindex.htm >. The listed species for the three counties (as of April 2002) are shown in Table 14.

Inventories of vascular plants in Richmond NBP were compiled from 1987 to 1992 by Virginia Commonwealth University and the Division of Natural Heritage of the Virginia Department of Conservation and Recreation (National Park Service 1994). A Virginia State rare plant, Collin's sedge (*Carex collinsii*), an obligative wetland species, was identified in the Cold Harbor unit by the inventory (National Park Service 1994). National Park Service policy requires that state-listed plants be treated the same as federally listed plants.

Amphibians are considered valuable indicators of environmental quality, and populations are in a state of worldwide decline. The worldwide decline in amphibian populations was

Table 14. Virginia Department of Conservation and Recreation's Natural Heritage Program rare plants and animals in Chesterfield, Hanover, and Henrico counties.

Type	Chesterfield	Hanover	Henrico
Amphibians	Barking treefrog[d] (*Hyla gratiosa*)	tiger salamander[a] (*Ambystoma tigrinum*)	none
Invertebrates	yellow lance[c] (*Elliptio lanceolata*); Ohio river shrimp (*Macrobrachium ohione*)	dwarf wedgemussel[a,b] (*Alasmidonta heterodon*); yellow lance[c] (*Elliptio lanceolata*); yellow lampmussel[c] (*Lampsilis cariosa*); eastern lampmussel[c] (*Lampsilis radiata*); green floater[c] (*Lasmigona subviridis*); Virginia piedmont water boatman (*Sigara depressa*); silver-bordered fritillary (*Boloria selene*)	green floater[c] (*Lasmigona subviridis*); Atlantic pigtoe[d] (*Fusconaja masoni*); mottled duskywing (*Erynnis martialis*); fine-ribbed striate (*Striatura milium*)
Non-vascular plants	none	none	soft peatmoss (*Sphagnum molle*)

Table 14. (continued).

Type	Chesterfield	Hanover	Henrico
Vascular plants	sensitive joint-vetch[e] (*Aeschynomene virginica*); red milkweed (*Asclepias rubra*); a sedge (*Carex vestita*); Cuthbert turtlehead (*Chelone cuthbertii*); Virginia thistle (*Cirsium virginianum*); spreading pogonia (*Cleistes divaricata*); creamflower tick-trefoil (*Desmodium ochroleucum*); slim-leaf tick-trefoil (*Desmodium tenuifolium*); wild mudwort (*Dicliptera brachiata*); rattlesnake-master (*Eryngium yuccifolium*); sheep-laurel (*Kalmia angustifolia*); little-leaf sensitive-briars (*Mimosa quadrivalvis*); large white fringed orchid (*Platanthera blephariglottis*); savannah beakrush (*Rhynchospora debilis*); fasciculate beakrush (*Rhynchospora fascicularis*); two-formed pink (*Sabatia difformis*); southern purple pitcher-plant (*Sarracenia purpurea*); pineland squarehead (*Tetragonotheca helianthoides*); Virginia least trillium (*Trillium pusillum*); large-flowered camass (*Zigadenus glaberrimus*)	slim-leaf tick-trefoil (*Desmodium tenuifolium*); featherfoil (*Hottonia inflata*); little-leaf sensitive-briars (*Mimosa quadrivalvis*); southern purple pitcher-plant (*Sarracenia purpurea*); pineland squarehead (*Tetragonotheca helianthoides*)	sensitive joint-vetch[e] (*Aeschynomene virginica*); swamp pink[a,e] (*Helonias bullata*); red milkweed (*Asclepias rubra*); a sedge (*Carex vestita*); Cuthbert turtlehead (*Chelone cuthbertii*); Virginia thistle (*Cirsium virginianum*); New Jersey rush (*Juncus caesariensis*); dwarf chinquapin oak (*Quercus prinoides*); short-beaked baldrush (*Rhynchospora nitens*); Elliott goldenrod (*Solidago latissimifolia*); piedmont meadow-rue (*Thalictrum macrostylum*); Virginia least trillium (*Trillium pusillum*); large-flowered camass (*Zigadenus glaberrimus*); viperina (*Zornia bracteata*)

[a]State of Virginia endangered species
[b]Federal endangered species
[c]State of Virginia species of special concern
[d]State of Virginia threatened species
[e]Federal threatened species

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initially brought to the attention of the international community in 1989 at the First World Congress of Herpetology held in England. In the following decade, the amphibian decline issue has come to be regarded as an ecological emergency in progress.

Population declines involving a large percentage of the amphibian community continue to be documented, and there is growing evidence of a decline in populations in North America (Bury *et al.* 1995; Bury and Major 1997). Ranges of many species have been dramatically reduced, and species extinctions have occurred rapidly even in some protected areas. Furthermore, amphibian populations of multiple species around the world are experiencing a surge in bizarre and perplexing malformations. Although questions still remain, several potential causes of decline and/or malformations have emerged: climate change; habitat loss and fragmentation; introduced (exotic) species; environmental contaminants (e.g. pesticides); ultraviolet radiation; acid rain; disease (e.g. fungal and viral infections); parasites; and unsustainable harvest and trade. Concern that amphibian declines are precursors of threats to human health has invoked the attention of the public, research biologists, and policy makers. The amphibian-decline crisis demands that the status of amphibian populations be assessed rapidly and that where declines and/or malformations are apparent, such causes be identified, habitats managed, and recovery programs established.

No amphibian or reptile surveys have been conducted within the boundaries of Richmond National Battlefield Park. However, Mitchell and Reay (1999) have published "An Atlas of Amphibians and Reptiles in Virginia." This distribution atlas is based on species presence/absence in county collections. Matching species presence in Chesterfield, Hanover and Henrico counties reveals the potential complement of amphibian and aquatic-based reptile species for the park. Twenty species of frogs and toads may occur in the park, including Barking Treefrog (*Hyla gratiosa*), a state threatened species, and the Carpenter Frog (*Rana virgatipes*), a state rare species. Thirteen salamander species show distributions that include these counties, as well as eight species of turtles and four species of snakes. The box turtle (*Terrapene carolina carolina*) is known to exist in the park (Richmond NBP, pers. comm. 2000). The U.S. Fish and Wildlife Service considers this turtle to be one of the top ten most threatened species.

The park likely also contains a number of fish and aquatic invertebrates, but they too have not been surveyed. The aquatic biological assessment described in Project Statement RICH-N-011.000 (Appendix A) would provide information on the aquatic invertebrates. The number of fish species probably is limited by the size of the streams draining the park units. An assessment of the fish species present in the park units could be accomplished at the same time as the aquatic biological assessment. With a comprehensive inventory of water-dependent flora and fauna, the status of native species, the presence of additional rare, threatened, or endangered species, and the presence of invasive exotic species could be determined. Project Statement RICH-N-013.000 (Appendix A) is designed to conduct such a comprehensive inventory within the park.

INVASIVE EXOTIC SPECIES

The following general information on invasive species is summarized from Heffernan (1998). Alien plants, also known as exotic, non-native, or nonindigenous plants, are species intentionally or accidentally introduced by human activity into a region in which they did not evolve. Invasive alien plants escape cultivation and become agricultural pests, infest lawns as weeds, displace native plant species, reduce wildlife habitat, and alter ecosystem processes. Across the country and around the world, invasive alien plants and animals have become one of the most serious threats to native species, natural communities, and ecosystem processes. They also exact a costly toll from human economies that depend on resources and services provided by healthy ecosystems. Examples include destruction of vast areas of western rangelands, clogging of important waterways, and increased costs in maintaining open powerline rights-of-way.

Of the 4,000 alien plant species introduced to the United States that have escaped cultivation, approximately 400 are serious invaders. Half this total was introduced for horticultural uses. Others arrived accidentally in seed mixes, packaging materials, ship's ballast, and by other means. Invasive plants now infest more than 100 million acres. An Office of Technology Assessment study (1993) estimated that from 1901 to 1991, economic losses in the U.S. caused by 15 invasive plant species (not including agricultural weeds) were $603 million.

Once thought to be a problem only on farms or in lawns, invasive plants are now recognized as a threat to natural areas, parks, forests, and other sites in a more or less natural state. Land managers, weed scientists, foresters, ecologists, and other conservationists are joining together to face this challenge in ways that help conserve native species and natural communities and protect environmental quality.

Invasive alien plants typically exhibit the following characteristics:

- rapid growth and maturity;
- prolific seed production;
- highly successful seed dispersal, germination and colonization;
- rampant vegetative spread;
- ability to out-compete native species;
- high cost to remove or control.

An invasive plant infestation is like a slow-motion explosion, which, if left unchecked, may severely alter a site's natural, economic, aesthetic, and other cultural values. Management of invasive species while maintaining these values can appear to be a complicated and unending task. For this reason, planning and prioritizing are crucial. By articulating clear goals, gathering the best available information, and prioritizing actions based on the significance of an infestation's impacts and feasibility of control, land managers can identify how their time, effort, and money can most effectively be applied. Invasive species present a difficult challenge with no quick and easy solutions. Many unknowns exist regarding control methods and their efficacy, while there are limited budgets for managing invasive plants. Sometimes, the best course of action may be to do nothing.

The Virginia Department of Conservation's Division of Natural Heritage and the Virginia Native Plant Society have identified 115 invasive alien plant species that threaten or potentially threaten rare animal or plant species, natural areas, parks, and other protected lands in Virginia (< http://www.dcr.state.va.us/dnh/invlist.pdf >). The list carries no regulatory or statutory authority and is entirely advisory in nature. The Virginia Natural Heritage Program also conducted a study using vegetation sample plots to rank invasive exotic plant species in Virginia (< http://www.dcr.state.va.us/dnh/rankinv.pdf >). The top five species most frequently found in the vegetation sample plots were as follows: Japanese honeysuckle (*Lonicera japonica)*, Aneilema (*Murdannia keisak)*; Garlic mustard (*Alliaria petiolata)*; Japanese stilt grass (*Microstegium vimineum)*; and tree of heaven (*Ailanthus altissima)*. Four of these five species have been identified in most or all of the park units (see Vegetation section); the fifth, Garlic mustard, has been identified in the Malvern Hill unit (OCULUS 2000).

Resources for the control of invasive exotic species are usually limited. Therefore, a management activity is to rank invasive exotic species on the basis of: 1) significance of impact on the site; and 2) feasibility of control (Hiebert and Stubbendieck, 1993). Management strategies for invasive exotic species include: 1) Prevention. For a relatively unestablished species such as Garlic mustard, a simple management strategy is to be on a vigilant look out for its appearance, and deal with outbreaks as soon as possible, rather than to allow it to become established in the park. A routine biological monitoring program is key to the success of this strategy. 2) Restoration from human-induced disturbance of natural systems, such as disturbance of vegetation, soil, hydrologic regime, or nutrient levels. The term refers to restoration of ecological processes, such as succession, fire, hydrology, or grazing, after a human-induced disturbance. 3) Control methods include: mechanical, chemical, and biological. For example, at Beaver Dam Creek, chemical control is the only feasible option because of the reproductive particulars of the invasive exotic species present at the unit.

Executive Order 13112 was signed in 1999 and complements and builds upon existing federal authority to aid in the prevention and control of invasive species. E.O. 13112 mandates that the NPS will use reasonable means to control invasive exotic species, including the application of herbicides. According to E.O. 13112, Federal Agency Duties are as follows:

> (a) Each Federal agency whose actions may affect the status of invasive species shall, to the extent practicable and permitted by law,
>
> (1) identify such actions;
>
> (2) subject to the availability of appropriations, and within Administration budgetary limits, use relevant programs and authorities to: (i) prevent the introduction of invasive species; (ii) detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner; (iii) monitor invasive species populations accurately and reliably; (iv) provide for restoration of native species and habitat conditions in ecosystems that have been invaded; (v) conduct research on invasive species and develop technologies to prevent introduction and provide for environmentally sound control of invasive species; and (vi) promote

> public education on invasive species and the means to address them; and
>
> (3) not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction or spread of invasive species in the United States or elsewhere unless, pursuant to guidelines that it has prescribed, the agency has determined and made public its determination that the benefits of such actions clearly outweigh the potential harm caused by invasive species; and that all feasible and prudent measures to minimize risk of harm will be taken in conjunction with the actions.
>
> (b) Federal agencies shall pursue the duties set forth in this section in consultation with the Invasive Species Council, consistent with the Invasive Species Management Plan and in cooperation with stakeholders, as appropriate, and, as approved by the Department of State, when Federal agencies are working with international organizations and foreign nations.

In Virginia and Pennsylvania, 10 NPS units have banned together to form the Mid-Atlantic Network Exotic Pest Management Team (MAN-EPMT), a vegetation control cooperative. These units include Appomattox Court House National Historical Park; Booker T. Washington National Monument; Colonial National Historical Park; Eisenhower National Historic Site; Fredericksburg and Spotsylvania County Battlefields Memorial National Military Park; George Washington Birthplace National Monument; Gettysburg National Military Park; Petersburg National Battlefield; Richmond NBP; and Shenandoah National Park. Richmond NBP is strongly urged to participate and cooperate in MAN-EPMT by sharing experiences and learning from staff at other park units.

As stated above, Project Statement RICH-N-013.000 (Appendix A) is designed to determine the presence of any rare, threatened, or endangered species, along with the presence of invasive exotic species.

ADOPTING A PROACTIVE CULTURE TO PROTECT PARK LANDS

Following are brief chronologies of past investigations and actions that have occurred within several Richmond NBP units (all documents on file at Richmond NBP or as noted). These chronologies are included to 1) document past and existing problems within these units, and 2) serve as examples of how a more proactive culture among park staff and throughout the NPS might have prevented some of the water resources issues at Richmond NBP.

Beaver Dam Creek

In 1976 and 1977, Druss *et al.* (1977) performed an archeological investigation of the unit because of the impending Hanover County Sewer Project. In this report, they show a photograph of construction equipment stuck in the mud during installation of the new sewer line, suggesting that sediment may have been recently deposited.

In 1985, a doctoral dissertation by John Mudre, under the supervision of John Ney, was completed at Virginia Tech. Mudre (1985) investigated the contamination by and effects of highway-generated heavy metals in six roadside stream ecosystems, one of which was Beaver Dam Creek. He sampled for cadmium, lead, and zinc in: water, sediment, benthic invertebrates, whole-body fish, and fish tissues. In general, he found that concentrations of these metals were higher in sediments, benthic invertebrates, fish whole bodies, and fish tissue (liver, kidney, bone) in areas downstream of I-295 than upstream.

In April 1986, James Gregory and Charles Williams (Department of Forestry, North Carolina State University) visited the unit to evaluate the impacts of sedimentation from offsite development activity. They determined that construction of the apartment complex development to the east of the unit (Mill Trace Village) and installation of a sewer line caused adverse hydrologic impacts to the unit. They documented destabilization of the stream channel of the stream draining to the mill pond, breeching of a section of the earthen dam at the mill, inputs of tremendous amounts of sediment to the mill pond, deposition of a large sediment fan that extended to Beaver Dam Creek, delivery of increased sediment loads to Beaver Dam Creek, and burial of tree root systems by sediment, causing stress and mortality of trees. They stated, “There is no doubt that the sewer line construction site and the Mill Trace Village development, in particular, are the sources of the sediment in the park unit” (documents on file at Richmond NBP).

In May 1986, the National Park Service set up a series of siltation sampling points in Beaver Dam Creek, within the park unit. Accumulation of up to 9 inches of silt over a five-month period was documented.

On September 17, 1986, Sam Kunkle (Land-Use Hydrologist, NPS, Water Resources Division, Ft. Collins, CO) visited the Beaver Dam Creek unit to investigate urbanization impact problems (trip report on file at Richmond NBP). His report indicates that development of Mill Trace Village clearly impacted the park unit with large amounts of silt deposition from erosion during construction. In addition, he predicted that a planned development (Harbor Corral subdivision), located between Mill Trace Village and the unit would cause additional sediment deposition in the park unit.

On March 17, 1987, James Gregory (Associate Professor of Forestry, N.C. State University) submitted review comments on the “Development plans for Harbor Corral, Cold Harbor District, Hanover County, Virginia, November 16, 1986.” A summary of his review is as follows: 1) removal of vegetation for the development will increase runoff by reducing evapotranspiration; 2) installation of impervious surfaces and soil disturbance and compaction will reduce infiltration and subsurface flow capacity and cause increased surface runoff and erosion and sedimentation; and 3) surface runoff will be concentrated and flow that contributes to the stream can be expected to increase by at least 5-fold.

End chronology

The sedimentation at Beaver Dam Creek is clearly related to development inside and outside of park boundaries, i.e. installation of a county sewer line, building of apartment complexes, and possibly construction of Interstate 295. The influx of sediment to the park unit may have changed the stream course and caused damage to the mill site. Furthermore, the influx of sediment from off site may have facilitated the introduction of the invasive exotic vegetation (*Murdannia keisak*) that currently is prevalent at the site. Analysis of pre- and post-development aerial photography might indicate whether the site was naturally a wetland or if the influx of sediment created the wetland. Aerial photography analysis might also determine whether invasive exotic vegetation was introduced to the unit by the development and influx of sediment. What wetland and aerial photography analysis cannot do, however, is change the fact that the influx of sediment occurred. The influx of sediment only could have been reduced by action taken by park staff prior to or early on in the development that occurred inside and outside of park boundaries. Had park staff been more proactive in insisting on adequate sediment controls during construction, some or all of the existing problem may have been prevented. Should the park decide to proceed with a wetland analysis, and it is determined that the site was not a wetland prior to the influx of sediment, it would be costly to remediate the site (i.e. remove the sediment) and possibly be not fully successful.

Chickahominy Bluff

In June 1989, Gary Frazer, U.S. Fish and Wildlife Service, visited the unit to inspect an unauthorized wetland fill constructed by William Keck on the southeastern boundaries of the unit. The landowner had constructed a fill berm parallel to, and within the floodplain of, the intermittent stream that runs roughly along the southeastern boundary of the unit. The total amount of wetland filled was approximately 0.2 acres. The landowner had apparently been incrementally filling the area for several years.

In July 1989, Gary Pokrifka, Virginia Department of Conservation and Recreation, visited the unit to investigate flooding and sedimentation problems. He determined that excess sediment deposits originated from two sources: 1) a Ryan Home subdivision that was undergoing development, located on the opposite side of the stream from park property; and 2) a property immediately upstream and on the same side of the stream as park property belonging to William Keck, who was depositing fill material without erosion and sediment control practices in place. J.D. Thompson, Henrico County Erosion and Sediment Control Inspector, indicated that he would rectify the deficiencies related to the Ryan Home subdivision. Both sources of sediment were reported to the U.S. Army

Corps of Engineers, because it appeared the wetlands were being destroyed as a result of sediment discharge.

In March 1991, Tom Gunter, Virginia Department of Game and Inland Fisheries, visited the unit and determined that there had been significant impacts to wetlands because of channelization work conducted by a neighboring landowner. Alterations to the stream diverted the stream channel from park land onto neighboring land, which caused de-watering of the wetland area on park property and a much larger wetland area downstream of park boundaries.

In April 1991, Robert Hume, Army Corps of Engineers, recommended that the park restore the stream to its approximate original depth and width after erosion from the adjacent property had been halted. In addition, he indicated that the Corps would notify the violator (Maplewood Farm subdivision) to stop the runoff.

Also in April 1991, Gary Pokrifka, Virginia Department of Conservation and Recreation, revisited the site and determined that the Ryan Home subdivision appeared to have been stabilized, however, the fill operation continued to operate with no erosion and sediment controls. In addition, he noted another fill operation being conducted immediately downstream of park property and on the opposite side of the stream. This fill operation was also being conducted without erosion and sediment controls and was affecting the surrounding wetlands and the existing vegetation, including the trees.

In May 1991, park staff met with Army Corps of Engineers representatives regarding the two issues: 1) channelization of a creek and filling of a wetland by two adjoining neighbors (both Charles and William Keck); and 2) a siltation and filling problem created by the development and construction of the Maplewood Farm subdivision. In addition, they found five monitoring wells and four 55-gallon drums (three full) and noted a gasoline odor near the stream, upstream of the unit. The monitoring wells and drums belonged to the Citgo Gas Station on Mechanicsville Pike (State Route 360). The State Water Control Board and the Coast Guard had reportedly been notified.

End chronology

Like the Beaver Dam Creek unit, some of the sedimentation problems at the Chickahominy Bluff unit may have been reduced by involvement of park staff to minimize the effects of the construction and development outside of park boundaries.

Drewry's Bluff

Environmental problems at this unit include: 1) the instability of the bluff on the James River, upon which Fort Darling sits; 2) the Exxon Richmond Asphalt Terminal on the northern boundary of the unit, which discharges stormwater to an unnamed tributary that flows through the unit; and 3) a landfill within the southern portion of the unit, which discharges leachate to the unnamed tributary that flows through the unit. The unnamed tributary discharges to the James River. Following is a brief chronology of past investigations and actions that have occurred within the Drewry's Bluff unit, subdivided into the three main environmental issues (all documents on file at Richmond NBP).

Following is a summary of past investigations and actions concerning the instability of the bluff on the James River:

1970-a Project Construction Proposal in excess of 1.2 million dollars was approved to repair and stabilize about 100 feet of the bluff. The money was not programmed.

1975-a safety fence across the length of the bluff was constructed to prevent visitors from getting too close to the edge of the bluff. The fence was built too low and was easily jumped.

1976-the Soil Conservation Service proposed an expensive, complicated construction of a massive freestanding structure of riprap at the base of the bluff.

1987-NPS coordinated a bluff erosion study with two other local parks (Colonial and Petersburg), where general alternatives were discussed and possible solutions offered. Full stabilization costs were placed at several million dollars.

1990-Nancy Ibison (Shoreline Engineer, Virginia Department of Conservation and Recreation) met with Pete Baril and Erv Gasser at the unit for advisory assistance concerning shoreline erosion problems. She recommended 1) all trees and shrubs growing on the bank and within 50 feet of the bank edge should be cut; 2) selected sections of the bank should be reshaped to a 2:1 (horizontal:vertical) slope or flatter, and a vegetative cover established; 3) installation of a properly designed and constructed riprap structure; and 4) a properly designed and constructed bulkhead as an alternative to the riprap structure.

1992-A report was prepared by Virginia Geotechnical Services on a proposed slope stabilization project for Fort Darling. The report describes the subsurface exploration, geologic site reconnaissance, and a geotechnical evaluation. The slope is actively being eroded by the James River and historically significant Fort Darling will be destroyed by continued erosion of the bluff. The report concludes that remediation of the slope should include 1) reducing future erosion at the toe of the slope, and 2) regrading the existing slope to prevent slump-type failures as a result of erosion that has already taken place. Costs were estimated at 5 to 7 million dollars. The report was reviewed by Schnabel Engineering Associates. Schnabel disagreed with Virginia Geotechnical Services that the main cause of the erosion is the James River; Schnabel indicated that the normal freeze-thaw weathering cycle was the main cause. The U.S. Army Corps of Engineers independently reviewed the report and conducted site visits and agreed with Schnabel's views.

<u>End chronology</u>

Clearly if Fort Darling is to be preserved, stabilization of the bluff must occur. Proposed stabilization will have to undergo review by various government agencies, and appropriate permits will need to be applied for and obtained. Stabilization of the bluff will be costly.

Following is a direct quote from Richmond NBP's RMP (National Park Service, 1994) on this issue:

> "Develop a comprehensive, workable plan for this problem. Assist management in identifying the goals and objectives for Drewry's Bluff. Re-examine the recommendations of the bluff erosion conference. Fund soil bioengineering study. Explore any and all new concepts, procedures and expertise available. Obtain all clearances necessary, such as Section 106 and Environmental Assessment. This plan will be a decision making tool for determining whether the government will undertake the large expence (*sic*) of stabilizing the slope, or accepting the loss of the historic site.
>
> Make all administrators and NPS personnel aware of the problems, the results of inaction and the anticipated costs. The concept of "pay a little now or a lot latter" (*sic*) applies."

Following is a summary of past investigations and actions concerning the unnamed tributary that receives discharge from the asphalt plant:

1991-Sampling for the Exxon Richmond Asphalt Terminal was conducted on June 24, in compliance with NPDES Permit No. VA0056146 by Environmental Laboratories, Inc. Samples were collected from Outfall 001, after it had been discharging for approximately 30 minutes. Results were as follows: flow, 0.03 million gallons per day; temperature, 22º C; pH, 6.53; total organic carbon, 41.7 mg/L; oil and grease, <5 mg/L.

Also in **1991**, Engineering firm Dewberry and Davis performed an analysis of the upper 200 feet of the drainage swale that bisects the unit. They found moderate erosion problems and recommended installation of check dams and negotiation with Exxon to release water only through the existing 8-inch pipe. There are three cast iron pipes that serve as outlets for the storm-water detention pond: 8-inch, 15-inch, and 18-inch.

1992-Trip report by David Sharrow (Hydrologist, Planning and Evaluation Branch, NPS) indicated that drainage from the unit's parking lot and asphalt trail has created an erosional gully 150 feet in length and 1 to 2 feet deep in most places, but up to 5 feet deep in some locations. The report recommended installation of a culvert to transport water to the creek, starting at the parking lot drain. The County offered to assist with design of the drainage system.

2002-Cindy Kane (U.S. Fish and Wildlife Service) visited the site and made several observations and suggestions: there is evidence in the upper reaches of the creek of a discharge of what could be asphalt constituents (i.e. sections of the stream substrate looked and felt like asphalt, black and very hard). She observed a large erosion and sedimentation problem coming from the parking lot and suggested the installation of erosion control measures (i.e. rain garden, etc.). Upon Cindy's suggestion, Curt Linderman (Regional Water Program Permit Manager) was contacted regarding this issue. Ray Jinkens returned the call, committed to visiting the site and gave the following information: the asphalt plant is now operated by Central Oil Asphalt Company, who is permitted only to release rainwater collecting in berms around tanks.

End chronology

Although the tanks are located off park property, the upstream location indicates that a spill would impact the water resources of the park. It would be useful for the park to have a copy of the asphalt plant's document for park files, if one has been written. The park should investigate whether a "Spill prevention, control, and countermeasure plan" is necessary for this unit, even though the tanks are located outside of park property. If a plan is required for this particular case, it should be prepared and added to park files.

Because of new ownership of the asphalt plant, past problems of high releases of stormwater to the unnamed tributary that crosses park land apparently have ended (Kristen Allen, Richmond NBP, pers. comm. 2002).

The erosion problem in the unnamed tributary caused by runoff from the parking lot and asphalt trail has been partially addressed. The asphalt trail has been relocated, and the park has attempted to rip-rap the top of the gully. The erosion along the gully, however, has worsened. The park is presently making plans to re-engineer the parking lot to address the drainage issue. The park is urged to accept the County's offer to assist, as well as to consider BMPs in the redesign plans.

Following is a summary of past investigations and actions concerning the unnamed tributary that receives leachate from the landfill:

1972-Chesterfield County abandoned the 25-acre landfill (used since 1963) and donated it to the park in 1973. Capping of the landfill consisted of digging a hole and pushing the waste (primarily household refuse, including abandoned appliances) into the hole. County was to install four monitoring wells and two piezometers.

1985-U.S. EPA performed a site inspection of the landfill and described its operation and closing. The landfill was filled using the trench method (trenches were up to 36 feet deep). The landfill was closed in 1972, covered, and revegetated. This all occurred before the Virginia DEQ issued permits for landfills. The report indicates that samples of leachate and of the unnamed creek had concentrations of iron and cyanide that may pose a threat to aquatic life. Numerous polynuclear aromatic hydrocarbons (PAH's)—benzo(a)anthracene, benzo(a)pyrene, benzo(b)- and benzo(k)fluroanthene, phenanthrene, and pyrene—were detected in downstream tributary sediment samples.

1989-Report of subsurface exploration and monitoring well installation, prepared for Chesterfield County Department of General Services, by Virginia Geotechnical Services. The report describes the installation of four ground-water-monitoring wells (MW) and two piezometers, as well as the soil strata and the depth and characteristics of the refuse layer. The landfill cap ranges from a depth of two to eight feet and consists of a sandy lean clay and sandy silt with gravel in various amounts. Refuse was found below the cap at depths ranging from 25 to 38 feet. No ground water was found in the two piezometers, however, ground water was found at depths ranging from 41 to 47 feet in MWs 1, 3 and 4. Ground water in MW 2 was found at a depth of 27 feet, within the refuse zone.

Also in **1989**, Del Nimmo, National Park Service Water Resources Division, tested acute toxicity of creek water using *Ceriodaphnia*, Fathead minnows, Amphipods and lettuce germination, and chronic toxicity using *Ceriodaphnia*. Although there was no clear evidence of acute toxicity in any of the species tested, there was evidence of chronic toxicity in *Ceriodaphnia* in water downstream of the landfill. This was reported in 1994 by National Park Service Water Resources Division in "Assessment of an Urban Landfill on Tributary Water Quality" (see below). He also measured specific conductance in the unnamed tributary and found 700 micromhos per centimeter (μmhos/cm) in the Exxon lagoon, 4100 μmhos/cm near the confluence of the first leachate, and 2200 μmhos/cm at the James River.

1990-A Memorandum of Understanding was signed between Chesterfield County and NPS/Richmond NBP for the County to drain ponding surface water, grade the landfill, and upgrade existing drainage channels to prevent water from ponding on the landfill surface. The county also committed to performing a comprehensive geotechnical and hydrologic assessment of the site to determine what impacts the site may be having on the environment, and what corrective actions may be necessary. This included the following projects for completion in phases and subject to budgetary constraints: analyze existing landfill cover to determine the quantitative and qualitative suitability, perform soil profile and analysis in the possible clay borrow area to the west of the fill area to determine the quantity and quality of those soils, and install ground-water monitoring wells to determine the direction of ground-water flow and the water-quality impact of the landfill.

1990-1991-Central Virginia Labs and Consultants (CVLC) performed chemical analysis of ground-water samples: temperature, pH, specific conductance, total organic carbon, total organic halides, iron, lead, sodium, chloride, and hardness. Interpretation by Del Nimmo indicated differences in pH among well sites, which ranged from 4.6-7.8. This was interpreted to mean that materials in the landfill were affecting the pH of ground water. Specific conductance was much lower than the 1989 samples. MWs 1 and 3 had significantly higher organic carbon than the other MWs. Concentrations of lead and halides were not significant. He recommended that a Priority Pollutant Analysis be performed. Results of these analyses are shown in Table 15.

1991-Analytical Technologies, Inc. analyzed water from the four monitoring wells for volatile and semi-volatile organics. The following organic constituents were found:

MW-1: acetone (850 parts per billion, ppb);
MW-2: acetone (8400 ppb);
MW-3: acetone (47,000 ppb), 1,2-dichloroethane (11 ppb), tetrachloroethane (18 ppb);
MW-4: acetone (220 ppb), chloroform (68 ppb).

Del Nimmo suggested that the organic constituents were possibly the result of general ground-water contamination from sources other than landfill, because the well up-

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Table 15. Results of monitoring-well samples collected from the Drewry's Bluff unit, November 1990 – November 1991.

Water-Quality Parameter, unit	**MW1**	**MW2**	**MW3**	**MW4**
Wells sampled November 26-27, 1990				
pH, units	7.76	5.36	5.88	4.57
Temperature, º C	14.7	18.2	14.3	16.4
Specific conductance, micromhos per centimeter	400	103	332	186
Total organic carbon, mg/L	1.53	0.691	3.54	0.808
Total organic halides, mg/L	0.127	0.818	1.13	0.208
Sodium, mg/L	12	3.3	3.3	8.7
Lead, mg/L	0.002	<0.001	0.002	0.001
Iron, mg/L	<0.03	0.55	30	4.2
Chloride, mg/L	56	11	16	30
Hardness, mg/L	138	24	90	80
Depth to water, feet	47.35	31.36	42.48	47.41
Wells sampled March 18-19, 1991				
pH, units	6.49	5.01	5.92	4.16
Temperature, º C	13.7	17.9	13.5	15.2
Specific conductance, micromhos per centimeter	318	90.3	302	238
Total organic carbon, mg/L	1.26	2.61	2.42	1.04
Total organic halides, mg/L	0.023	0.041	0.007	0.018
Sodium, mg/L	18	3.6	10	15
Lead, mg/L	<0.001	<0.001	<0.001	<0.001
Chloride, mg/L	56	11	21	54
Hardness, mg/L	72.3	9.77	68.4	51.1
Depth to water, feet	47.43	31.27	43.47	47.2
Wells sampled June 26, 1991				
pH, units	5.73	--	5.54	4.41
Temperature, º C	21.2	--	17.5	18.1
Specific conductance, micromhos per centimeter	316	--	265	174
Total organic carbon, mg/L	0.513	--	2.96	0.892
Total organic halides, mg/L	0.019	--	0.009	0.006

Sodium, mg/L	12	--	9.6	9.7
Lead, mg/L	<0.001	--	0.001	<0.001
Iron, mg/L	0.78	--	18	4.7
Chloride, mg/L	65	--	21	42
Hardness, mg/L	100	--	110	49
Wells sampled November 26-27, 1991				
Depth to water, feet	52.39	--	47.52	47.00

[n=, number of samples; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; $NO_2 + NO_3$, nitrite plus nitrate; NH_4, ammonium; NO_3, nitrate; µg/L, micrograms per liter]

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gradient of the landfill (MW4) also contained them. Metal concentrations were not found to be of concern at the time. A letter detailing these results was sent to Chesterfield County.

Also in **1991**, the park received money from the Regional Hazardous Materials funding source to remove exposed refuse from the slope adjacent to the land fill (drums, water heaters, tanks, tires, concrete, etc.). Two drums were sampled and determined to be hazardous waste. They were disposed of in an appropriate landfill.

Also in **1991**, Colorado State University Soil Testing Laboratory analyzed samples collected from the monitoring wells on July 26, 1991 (Table 16).

Table 16. Results of monitoring-well samples collected from the Drewry's Bluff unit, July 1991.

Water-Quality Parameter, unit	**Range in Value**
Calcium, mg/L	4.5-26.4
Magnesium, mg/L	1.9-7.3
Sodium, mg/L	2.8-14.8
Potassium, mg/L	6.4-10.0
Boron, mg/L	<0.01-0.02
Phosphorous, mg/L	<0.1
Aluminum, mg/L	<0.1-1.0
Iron, mg/L	<0.01-5.87
Titanium, mg/L	<0.01-0.07
Manganese, mg/L	0.06-2.39
Zinc, mg/L	0.01-0.05
Copper, mg/L	<0.01-0.04
Nickel, mg/L	0.02-0.04
Molybdenum, mg/L	<0.01
Cadmium, mg/L	<0.01

Chromium, mg/L	<0.01
Strontium, mg/L	0.04-0.16
Barium, mg/L	0.03-0.47
Lead, mg/L	<0.05-0.05
Vanadium, mg/L	<0.01-0.01
Silicon, mg/L	10.11-15.13

[All values given as the range in concentration for the sampling period shown; mg/L, milligrams per liter]

Also in **1991**, Erv Gasser (previous NRM Specialist) and Pete Baril (previous Chief Ranger) met onsite with Jim Perry (Chesterfield County Landfill Engineer) to discuss plans for re-capping the landfill. They also discussed a drainage issue along the park road possibly caused by the landfill (this was expected to be corrected by re-grading the landfill). Chesterfield County re-capped and graded the landfill with 35,000 cubic yards of sandy clay soil.

1994-Report on research done from 1989-1992 by National Park Service Water Resources Division entitled "Assessment of an Urban Landfill on Tributary Water Quality" (Nimmo *et al.* 1994). Reported on acute toxicity tests on tributary water and sediments using three aquatic organisms and one plant species. It was concluded that toxic conditions to aquatic life did not exist. Priority Pollutant Analysis of tributary water and sediments and water from the monitoring wells in the landfill did not reveal organic or inorganic chemicals at hazardous levels. An analysis of metals in the tributary water and sediments suggested that metals entering the tributary through landfill leachates are precipitating out of the water, armoring the sediments and preventing the establishment of permanent aquatic life.

1996-Park received reports from Chesterfield County on sampling performed by CVLC throughout the year. Data were interpreted and commented on by Roy Irwin (NPS, Water Resources Division). He found the data on metals and organics to be uniformly inconclusive because detection levels were too high. He recommended a complete scan of metals, PCB's, organochlorine pesticides, PAH's, and alkyl PAH's using up-to-date detection levels.

Also in **1996**, Draper Aden Associates (consulting engineers) described the installation of a slotted PVC pipe in an excavated seep, and three permanent sampling stations along the creek (marked with 3-foot wooden stakes, steel survey rods and flagging). Samples were taken at each site and analysis was done by CVLC. Results of this sampling event were summarized and interpreted by Draper Aden Associates as follows: organics were found in the leachate, but not the tributary, and included [Bis(2-ethylhexyl)phthalate (a suspected lab contaminant), benzene (exceeds drinking water standard), chlorobenzene, and naphthalene]; also found barium, cobalt, copper, lead, and zinc in tributary, but levels were much lower than in leachate. Seven out of ten heavy metals found in leachate exceeded safe drinking water standards.

Also in **1996,** Steven Zylstra (U.S. Fish and Wildlife Service) visited the site, examined park records and made several conclusions/suggestions: within the lower 1/3 of the creek, there was a rust-colored substance (oxidized iron) coating the sediments along with a thick coating of whitish precipitate (possibly oxidized aluminum or some other metal) and there was a scum covering some areas along the sides of the creek; seeps on the landfill side of the slope exhibited similar reddish color and precipitate. There was little variation in pH between visually impacted areas vs. unimpacted areas, however, the conductivity increased dramatically in the visually impacted area. The pH readings from the landfill monitoring wells were low to neutral (4.6-7.4). This low pH water would dissolve the metals and allow them to be transported to the seeps near the creek; organics are not expected to be a problem; the National Park Service needs to document biological impairment of the creek by collecting benthic macroinvertebrate data above and below the seeps. The National Park Service needs to demonstrate to the county that the impairment is a result of the landfill and encourage the county to address the problem. They may have to drill new wells to intercept the groundwater before it reaches the seeps and pump and treat it off site.

1998-Stream sediment was sampled by the park and analyzed by Texas A&M University for polynuclear aromatic carbons (PAH's), organochlorine pesticides, polychlorinated biphenyls, total organic carbon. Interpretation by Roy Irwin was as follows: almost all of the hazardous metals (all except boron and molybdenum) are much higher in the landfill's zone of influence (sites 3, 4, and 5). Arsenic, lead and beryllium were particularly high and above concern benchmarks. Nearly all of the PAH's and most of the alkyl PAH's were well above concern benchmarks at site 3, somewhat elevated at site 4, and slightly elevated at site 5. PCB's are well above concern benchmarks at site 3 and somewhat elevated at site 4. He recommended determining the levels of ammonia in the ground water, as this might be the solvent moving these contaminants to the creek. He also recommended going to the county with this information and encouraging them to further monitor and better remediate this issue.

2002-Issue was re-introduced to Roy Irwin, who passed the information along to Pete Penoyer (NPS, Ft. Collins) and Carl Wang (NPS, Washington Office Hazmat Group). Carl Wang suggested that the issue required the CERCLA process and recommended that the park conduct a Preliminary Assessment/Site Investigation and Responsible Party search. Money was requested from the Regional Hazardous Materials funding source for this purpose.

Also in **2002-**Cindy Kane (U.S. Fish and Wildlife Service) visited the site and made several observations and suggestions: she expressed concern over the reddish covering on the sediments, etc. and did a preliminary sampling of macroinvertebrates. The creek was found to be nearly devoid of life. Insufficient guidance has been given to park staff regarding types of analyses to be performed, including selection of a laboratory that could provide useable detection limits.

Also in **2002**-Jeffrey McKnight (Virginia DEQ) visited the site and expressed concern over exposed trash on the landfill slope and a seep emanating from the toe of the slope.

A complaint in this regard was sent to Chesterfield County. Charles Dayne (County of Chesterfield) responded to the complaint and agreed that the landfill seep appears to be affecting the creek. The county has contacted an environmental firm to make recommendations for some level of remediation.

<u>End chronology</u>

The park has had the burden of the landfill for three decades. From the preceding chronology, it appears that NPS staff has received conflicting information and has developed no clear course of action for dealing with the landfill.

It is not clear whether the CSU Soil Testing Laboratory analyzed for dissolved or total recoverable concentrations in the monitoring well samples in 1991. Some of the same constituents were analyzed in water collected from the unnamed tributary on November 1, 2001 during the USGS Level I Water Quality Inventory and Monitoring. Relative to the water in the monitoring wells analyzed in 1991, water in the unnamed tributary had increased sodium and potassium, greatly increased boron, iron, and manganese, and decreased aluminum in 2001. Dissolved ammonia in the stream water greatly exceeded the Virginia Water Quality Chronic Ammonia Criteria for Freshwater. These results suggest that leachate from the landfill is contributing to the unnamed tributary.

The landfill issue and its possible impacts to the unnamed tributary need to be resolved. One possible resolution would be to enter the CERCLA process, which would include performing a comprehensive hydrogeologic study of the landfill. Such a study would include determination of ground-water levels and direction of flow, and determination of concentrations of a wide variety of organic and inorganic constituents in ground water, stream water, and streambed sediment, using appropriate sampling techniques and laboratory detection limits. At the time of this plan, Richmond NBP had requested funding from the National Park Service HAZMAT monies for this purpose.

<u>Fort Harrison</u>

Date unknown: a gasoline leak at a convenience store near the north end of the unit contaminated one residential well (Welchlan residence) and threatened two other adjacent wells. The store responded to the leak by offering to run municipal water to the residences, for which the park would have to grant a right-of-way for the pipeline. A right-of-way was being negotiated and an archeological survey was pending (scoping report file at WRD/NPS, Ft. Collins).

1992-Two monitoring wells were installed in suspected wetlands for monitoring by NPS once a month for one year, starting in January. The wetlands inventory was being conducted by Jim Johnson, Amy Helm, and Dave Mitcham of Virginia Tech (scoping report file at WRD/NPS, Ft. Collins).

1999-Aegis Environmental, Inc. prepared a “Spill prevention, control, and countermeasure plan” (SPCC) for this unit. Such a plan is required by the U.S. EPA to be maintained at the facility in accordance with regulations contained in Title 40, Code of Federal Regulations Part 112 (40 CFR 112). A SPCC is required at a non-transportation related facility if the capacity of any aboveground oil storage tank exceeds 660 gallons, or if the aggregate storage capacity exceeds 1,320 gallons or 42,000 gallons of underground storage capacity, and if an oil spill could reasonably be expected to reach navigable waters. This park unit has one 500-gallon aboveground diesel fuel tank, one 2,000-gallon aboveground gasoline tank, and one 275-gallon used oil tank inside an equipment garage. There have been no past spill incidences.

End chronology

Park staff should have followed up on the 1992 ground-water study conducted by Virginia Tech by requesting the results of the study and a copy of the final report. At a minimum, the ground-water level data could have been added to park files.

According to park staff, there have been complaints from parkland neighbors concerning standing water in the "moat" situated between the park road and the earthworks. The neighbors have expressed concern that the moat acts as a breeding ground for mosquitoes and have requested that it be drained. It is not clear whether the moat would exist without the road or if installation of the road created the moat. Nevertheless, the moat functionally acts as a wetland and should be managed according to NPS policy (Director's Order 77-1). The neighbors should be given educational literature regarding installation of bat houses and purple martin houses as a defense against mosquitoes, and the necessity of protection of federal wetlands. The park may address the mosquito problem in the future as new technologies are developed. In addition, the Federal Highway Administration and the Virginia Department of Transportation could be contacted for advice on alleviating any drainage problems related to the road. Any action in the wetland to alleviate drainage problems, however, would require compliance under the NEPA, Section 404 of the Clean Water Act, and NPS Director's Order 77-1.

Malvern Hill/Glendale

1991-the Henrico County Board of Zoning Appeals issued a conditional use permit to a local company to allow gravel mining on lands adjacent to the unit. Up to 350 acres were mapped for future mining operations.

End chronology

Park staff is urged to keep abreast of possible gravel mining and other proposed developments near park lands and take preventative action.

Land-Use Decisions

Most of the important land-use decisions made near a protected area involve elected local officials, citizen boards and commissions, and professional planning staffs at the city and county levels, with input from a large number of citizens and other agencies. National

Park Service units, in general, have been slow to participate in these planning and decision-making activities, despite the profound effects that external land-use changes are having on their ability to achieve natural-resource management objectives. With regard to streams and their watersheds, park units whose land base does not include the headwater areas are either the conduit or repository of water pollution from upstream sources. Given the above chronologies, Richmond NBP has been slow to participate in planning and decision-making activities. Many of the water-resources impacts to the units of Richmond NBP are clear examples of this.

There are a number of ways (listed below, after Wallace 1999) that park staff can legitimately participate in local land-use decisions in order to influence the location, extent, type, and spatial patterns of development near Richmond NBP:

- Designate staff to be assigned to work with a wide variety of local government, landowners, homeowners' associations, and nonprofit organizations in order to address adjacent land-use issues.

- Conduct a GIS-based inventory of the park units with the following layers: 1) a base map showing current land use, infrastructure, ownership, and zoning; 2) a theme showing unique ecosystem components that extend beyond boundaries (e.g. streams and riparian habitats); and, 3) a theme depicting current and potential development activity as indicated by projects under review, ownership characteristics, available infrastructure, quantity of land for sale, and volume of land recently sold.

- Model what build out (the subdivision and development of all adjacent land) on adjacent lands will look like. This is a powerful planning exercise that superimposes the infrastructure, development, and use patterns of built-out developments with similar zoning on top of existing land uses that are not yet built out.

- Participate in the development or revision of the comprehensive (master) plans for the counties and cities adjacent to the park. Training may be required.

- Participate in the development or revision of the land-use code for the counties and cities adjacent to the park.

- Propose the creation of an overlay zone near the park.

- Participate in the review of any development proposals that could affect management objectives.

- Collaborate with local open-space programs and efforts to protect agricultural lands.
- Develop a memorandum of understanding with counties and cities that codifies mutual concerns and describes how to initiate the actions listed above.

- Use these opportunities to be an advocate of land and community health.

In addition, park staff is encouraged to work with local authorities to implement Best Management Practices (BMPs) on land surrounding and within park units. For example, the Virginia Department of Conservation and Recreation has a Virginia Stormwater Management Program (< http://www.dcr.state.va.us/sw/stormwat.htm >). Information from the web site may be applicable to controlling stormwater within park units, e.g. around parking lot drains and maintenance facilities. Potentially useful references for park managers include Northern Virginia Planning District Commission (1996), Horner *et al.* (1994), and Schueler (1987).

ADDITIONAL RECOMMENDATIONS

Education and Administration

Education of the visiting and general public on water resource issues in Richmond NBP provides a rare opportunity to tie together cultural history and natural history. Such an interpretation may make environmental studies more attainable for students, teachers, and the public. Some examples include: 1) the influence of wetlands on the outcome of the battles of Gaines' Mill and Cold Harbor; 2) the natural landscape features at Chickahominy Bluff, Drewry's Bluff, and Malvern Hill, created by the erosive forces of water, that provided key vantage points during the war; and 3) the bluff and wetland area at Beaver Dam Creek, that allowed installation of the mill.

A focus that is separate from the Civil War history of the park but is included in the interpretation of the site may serve to integrate the two in the mind of the public. Examples of educating the public on environmental issues, not directly related to Civil War history, include: 1) the sedimentation at Beaver Dam Creek, related to development outside of park boundaries, and which may have changed the stream course, and possibly have brought in the invasive exotic vegetation that is prevalent at the site; 2) the sedimentation at Chickahominy Bluff from development outside of park boundaries; and 3) the erosive forces of the James River and natural weathering (freeze-thaw cycle) at Drewry's Bluff, which eventually will cause the bluff to fail.

Cultural Landscape Reports and GIS Needs

A cultural landscape report exists for the Gaines' Mill unit (Land and Community Associates 1999), and one is in draft for the Malvern Hill unit (OCULUS 2000), but comparable reports have not been published for the other units. The cultural landscape report for the Gaines' Mill unit calls for "…clearing and thinning vegetation on the Boatswain Creek uplands to reestablish historic military sight lines and approaches." Terrain and vegetation maps of portions of both the Cold Harbor and Gaines' Mill units as they existed during the battles have been interpreted and drawn by C.R. Dickinson in 1988 and 1990, respectively.

In order to preserve both cultural and ecological landscapes, data from the existing cultural landscape maps should be entered into a GIS system for both units. Likewise, data from the current wetlands study for all units need to be entered into a GIS system.

Once in a GIS system, these data can be overlaid to determine whether any landscape alteration designed to emulate the landscape at the time of the battles may impact any wetlands or riparian buffers.

Vegetation Maintenance

Currently there is no mowing or weed cutting in the vicinity of the streams in any of the units (Jerry Helton, Richmond NBP, pers. comm. 2000). Any future changes in vegetation maintenance along streams and in riparian areas should be carefully evaluated to determine potential impacts. Any potential impacts need to be evaluated in light of the Agreement of Federal Agencies on Ecosystem Management in the Chesapeake Bay.

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APPENDICES

APPENDIX A

Proposed Water Resources-Related Project Statements

PROJECT STATEMENT NO. RICH-N-011.000
TITLE: MONITOR LAND-USE IMPACTS ON WATER QUALITY

FUNDING STATUS: FUNDED: 0.0 UNFUNDED: 12.0

BACKGROUND

<u>The Park and Surrounding Land Use</u>

Richmond National Battlefield Park (Richmond NBP) is in and adjacent to the city of Richmond, Virginia. The park is spread out among 11 geographically separated units, which collectively cover 1,366 acres. The park units are primarily to the east, northeast and southeast of the city of Richmond; as such, the park is in an urban/suburban environment. Much land previously in rural or agricultural land use has been converted to suburban land use. Competing pressures on parkland, such as encroaching development, existing development within and outside of park boundaries, nonpoint-source pollutants, proximity to point-source pollutants, natural processes, and future changes in land use are potential threats to the integrity of water quality and quantity in the park. The small size of the individual portions of the park make each unit more susceptible to influences from surrounding land use than a large intact tract of park land; the smaller a tract of land, the larger the portion that will be affected by a given disturbance or pollutant.

Because of these pressures and potential degradation to the natural resources in the park, the impacts of land use on water quality in the park units need to be monitored. The initial collection of monitoring data (i.e. baseline) is the first step in developing a plan to control nonpoint-source pollution from land use. If water-quality impairment is noted, the park can work with the appropriate political and regulatory entities in the application of best management practices (BMPs -- the primary means to protect water quality from nonpoint-source pollution). The effective application of BMPs requires regular monitoring to determine that the BMPs were applied as planned. This information must be fed back to managers in order for them to assess where the BMP planning and implementation process is working. This implementation monitoring feedback loop is a crucial link in helping to ensure that BMPs are properly integrated into ongoing management activities. Once BMPs are in place, continued water-quality monitoring is required to ensure that there is no degradation of water quality. These data must be evaluated on a continuing basis, and a degradation in water quality probably will force a change in the procedures being used to limit nonpoint-source pollution or determine if additional control measures should be undertaken.

The Concept of Biological Integrity and its Assessment

The phrase "biological integrity" was first used in 1972 to establish the goal of the Clean Water Act: "to restore the chemical, physical, and biological integrity of the Nation's waters." This mandate clearly established a legal foundation for protecting aquatic biota. The vision of biological integrity, however, was not reflected in the act's regulations for implementation. Those regulations were aimed at controlling or reducing release of chemical contaminants and thereby protecting human health; the integrity of biological communities was largely ignored (Karr 1991).

Biological integrity refers to the capacity to support and maintain a balanced, integrated, and adaptive biological system having the full range of elements (e.g. populations, species, assemblages) and processes (e.g. biotic interactions, energy dynamics, biogeochemical cycles) expected in a region's natural habitat (Karr *et al.* 1986). The biological integrity of water resources is jeopardized by altering one or more of five classes of environmental factors: physical habitat, seasonal flow of water, the food base of the system, interactions within the stream biota, and chemical contamination (Karr 1991). Urbanization, for example, compromises the biological integrity of streams by severing the connections among segments of a watershed and by altering hydrology, water quality, energy sources, habitat structure, and biotic interactions.

Water managers are increasingly being called upon to evaluate the biological effects of their management decisions. No other aspect of a river gives a more integrated perspective on its health than the condition of its biota. Widespread recognition of this and the continued degradation of our water resources have stimulated numerous efforts to improve our ability to track aquatic biological integrity (Davis and Simon 1995). Comprehensive, multimetric indexes (Barbour *et al.* 1995) were first developed in the Midwest for use with fishes (Karr 1981; Fausch *et al.* 1984; Karr *et al.* 1986), and modified for use in other regions of the U.S. (Miller et al. 1988) and with invertebrates (Ohio EPA 1988; Plafkin *et al.* 1989; Kerans and Karr 1994; Deshon 1995; Fore *et al.* 1996). The conceptual basis of the multimetric approach has now been applied to a variety of aquatic environments (Davis and Simon 1995), including large rivers, lakes, estuaries, wetlands, riparian corridors, and reservoirs, and in a variety of geographic locations (Lyons *et al.* 1995). These indices incorporate many attributes of aquatic communities that cover the range of ecological levels from the individual through population, community and ecosystem. Biological community measures offer the advantage that they respond to a variety of stressors, they integrate impacts over time (thereby reducing the amount of sampling), and they directly assess the achievement of a primary objective of the Clean Water Act (Barbour *et al.* 1995). The original multimetric index, the Index of Biotic Integrity (Karr *et al.* 1986), summarized stream fish collection data into 12 ecological characters from three categories: species richness and composition, trophic composition, and fish abundance and condition. Each metric is scored as poor, good, or excellent relative to an 'expected community' from a natural undisturbed ecosystem of similar size and characteristics from the same ecoregion. The strength of these multimetric indices is that many factors that affect biotic integrity can be seen or measured. The goal is to understand and isolate, through sampling design and analytical procedures, patterns that derive from natural variation in environments.

Status of Stream Water Quality/Biological Integrity and Local Attempts at Biological Assessment

While it appears that the quality of water is good within the headwater streams flowing through the park units, nonpoint-source pollutants associated with increasing residential development could adversely affect existing water quality. Potential contamination could derive from such nonpoint sources as subdivision development, runoff associated with agriculture and developed areas, septic system leachate, and lawn and garden chemicals. Residential development often results in the reduction of infiltration areas by the creation of impervious surfaces, which can increase storm-water runoff and alter discharge and hydrologic patterns of streams. This, in turn, may lead to additional sediment loading and channel scour in the receiving stream. Improperly designed slope development or poor construction practices can also increase surface erosion and sediment load. Many of the residences surrounding the park units also contain expansive lawn areas, which undoubtedly receive applications of fertilizers and pesticides. Little information is currently available regarding the types and amounts of chemicals applied or the potential for runoff of these chemicals into adjacent streams. Therefore, development in the watersheds draining the park units has the potential to impair surface- and ground-water quality, reduce surface- and ground-water quantity, and negatively affect biological resources in the units.

The paucity of specific information on surface-water features (wetlands and riparian areas), surface- and ground-water quantity and quality, and aquatic biology compromises any effective water-resources planning. Without sufficient water-resource information and adequate baseline data, any impacts on water resources will remain undetected and changes cannot be documented. However, a comprehensive water-quality-monitoring program for surface and ground waters is not warranted given that the streams are small and drain headwater watersheds – impacts from adjacent land use are more immediate and there are few cumulative impacts from upstream land use. Additionally, at present, park financial and staff limitations would not sustain a long-term comprehensive monitoring program with adequate quality assurance and control. What is needed is a sustainable, scientifically credible, ‘canary-in-the-mine’ monitoring program that is efficient and cost-effective. This type of monitoring program does not need to be conducted on a frequent basis because all that is desired is a warning of resource degradation. If the distinct changes in the data determine that a water-resource problem exists, then more intensive study is needed to determine the exact nature and cause of the problem.

In Virginia, the 1998 Biological Monitoring Program of the Department of Environmental Quality uses the study of bottom-dwelling macroinvertebrate communities to determine overall water quality. This monitoring program is composed of stations examined twice annually, during the spring and fall. The U.S. Environmental Protection Agency’s Rapid Bioassessment Protocol II (Plafkin *et al.* 1989; Table 1) has been employed since the fall of 1990 as a standardized and repeatable methodology. The results of this protocol produce water quality ratings of nonimpaired, moderately impaired, and severely impaired.

Table 1. Criteria[a] for the characterization of biological condition for Rapid Bioassessment Protocol II (after Plafkin *et al.* 1989).

Metric	Biological Condition: Non-Impaired	Biological Condition: Moderately Impaired	Biological Condition: Severely Impaired
1. Taxa Richness	Comparable to the best situation to be expected within an ecoregion. Balanced trophic structure. Optimum community structure (composition and dominance) for stream size and habitat quality.	Fewer taxa due to loss of most intolerant forms. Reduction in EPT taxa.	Few taxa present. If high densities of organisms, then dominated by one or two taxa. Only tolerant organisms present.
2. Family Biotic Index (modified)			
3. Ratio of Scrapers/ Filtering Collectors[b]			
4. Ratio of EPT[c] and Chironomid Abundances			
5. % Contribution of Dominant Family			
6. EPT Index			
7. Community Similarit Index[d]			
8. Ratio of Shredders/Total[b]			

[a] Scoring criteria are generally based on percent comparability to a reference station.
[b] Determination of Functional Feeding Group is independent of taxonomic grouping.
[c] Three orders of aquatic insects (Ephemeroptera, Plecoptera, and Trichoptera) that are primarily intolerant of degraded conditions.
[d] Community Similarity Indices are used in comparison to a reference station.

The procedure evaluates the macroinvertebrate community by comparing ambient monitoring network stations to "reference" sites. A reference site is one that has been judged to be representative of a natural, unimpaired waterbody. An additional product of this evaluation is a habitat assessment, which provides information on the comparability of each stream station to the reference site.

PROBLEM STATEMENT

The park will explore further the use of multimetric indices (or rapid bioassessment protocols) for use in its tributary systems. This exploration is necessary because of the: 1) lack of knowledge of stream aquatic biology and status of water quality; 2) development potential of tributary watersheds; and 3) need to establish a long-term, cost-effective assessment program for watersheds where none exists. The systematic, biological assessment of species assemblages using multimetric indexes is currently a very practical and cost-effective approach to determine if human actions are degrading biological integrity (Davis and Simon 1995). Such monitoring provides both numeric and narrative descriptions of resource condition, which can be compared among watersheds, across a single watershed, and over time (Karr 1991), and it does so at costs that are often less than the cost of complex chemical monitoring. Furthermore, this monitoring can evaluate management actions and decisions, e.g., the effectiveness of BMPs such as riparian buffers. Costs per evaluation are relatively low for ambient biological monitoring. Based on a decade of sampling and including equipment; supplies; and logistical, administrative, and data-analysis and interpretation activities, benthic invertebrates cost $824/sample and fish cost $740/sample (Yoder and Rankin 1995) in comparison with chemical and physical water quality ($1,653 per station) and bioassays ($3,573 to $18,318 per assay).

The Index of Biotic Integrity (IBI; Karr 1981), the first of the multimetric indexes and centered on fish communities, was conceived to provide a broadly based and ecologically sound tool to evaluate biological conditions in Midwestern streams. The IBI and other, similar indexes are based on a series of assumptions and intuitions of how biotic assemblages change with increased environmental degradation. A single sample from a stream reach is evaluated using 12 metrics to determine the extent to which the resident biotic community diverges from that expected of an undisturbed site in the same geographic area and of the same stream size (Table 2). Unlike efforts to define chemical criteria that do not take variation by geographic region into account, this approach explicitly recognizes natural variation in water-resource conditions. Ratings are assigned, summed, and placed into integrity classes (excellent, good, fair, poor, and very poor) to provide an assessment of the biological integrity or health of a system.

Table 2. Typical effects of environmental degradation on biotic assemblages (from Fausch *et al.*1990).

1. The number of native species, and those in specialized taxa or guilds declines
2. The percentage of exotic or introduced species or stocks increases
3. The number of generally intolerant or sensitive species declines
4. The percentage of the assemblage comprising tolerant or insensitive species increases
5. The percentage of trophic and habitat specialists declines
6. The percentage of trophic and habitat generalists increases
7. The abundance of the total number of individuals declines
8. The incidence of disease and anomalies increases
9. The percentage of large, mature, or old-growth individuals declines

10. Reproduction of generally sensitive species declines
11. The number of size- and age-classes declines
12. Spatial or temporal fluctuations are more pronounced

DESCRIPTION OF RECOMMENDED PROJECT

Biological monitoring of tributary streams in Richmond NBP will be based on the premise that biological integrity can be measured in terms of the composition, structure, and function of resident biotic communities. Because fish and benthic macroinvertebrate communities are sensitive to and integrate diverse aspects of their environments, including human-induced alterations, they serve as continual monitors of biotic integrity.
In an effort to foster partnering and to reduce any duplicative efforts, the park will contact the Virginia Department of Environmental Quality about the possibilities of a pilot study that would: 1) sample the habitat and benthic macroinvertebrate communities of the tributaries; and 2) use the benthic macroinvertebrate based multimetric index, Rapid Bioassessment Protocol II (Plafkin *et al.* 1989). Depending upon the level of state involvement, the park could conduct its own biological assessment program (with appropriate training and use of volunteers), conduct the sampling and contract to the state the identification and analysis phases, or just contract to the state all phases (sampling, identification, and analysis). The ultimate goal would be to establish two permanent (one for each park unit), park-based, stream sampling stations as part of the Virginia Department of Environmental Quality's monitoring and assessment program. To this end, the park would be able to assess tributary biological integrity on a regular basis with minimal personnel and monetary investments.

A biological-monitoring plan ($3K, first year only) will be developed that provides detailed technical guidance for completing the field studies, including the following information:

- Final study station locations;
- Reference station locations;
- Field protocols and sampling gear requirements for assessing habitat conditions and sampling benthic macroinvertebrate and fish communities;
- QA/QC protocols for sample handling, record keeping, and chain of custody;
- Field safety instructions; and,
- Schedule.

The monitoring plan will be peer-reviewed by personnel from the Water Resources Division of the National Park Service and the Virginia Department of Environmental Quality prior to implementation of the field studies.

Habitat and benthic macroinvertebrate assessments (combined cost is $3K/year) will be conducted at both monitoring stations once per year (time of year to be determined by Virginia Department of Environmental Quality) for the 3-year project. The 3-year project is intended to give enough time to implement and refine the monitoring plan, assess temporal variability, solidify the program, and prepare the park for continued, long-term monitoring. After the 3-year project, the park will absorb the costs of the monitoring program (i.e. approximately $3K/year plus staff time). However, sampling of the monitoring stations could be extended to once every two years. This is not the preferred approach, yet it is still viable, i.e. it would still provide an assessment of degradation of park resources. The possibility exists, however, that it would not be as timely an assessment as that on an annual basis.

Habitat assessments will be conducted at all monitoring stations following the procedures outlined in Plafkin *et al.* (1989). These procedures include an evaluation of the immediate watershed, substrates, stream width, and general water-quality conditions.

Benthic macroinvertebrates will be sampled at each monitoring station following the semi-quantitative techniques described in Plafkin *et al.* (1989). This multi-habitat method could be modified to maximize efficiency of fieldwork and analysis. This could involve compositing samples from the various habitats for analysis and data evaluation.

A numerical value will be calculated for each metric of Rapid Bioassessment Protocol II. Values will then be compared to values derived for the same metrics at corresponding reference stations. Each metric will be scored according to its percent comparability to the reference value. Scores for the individual metrics will then be totaled and compared to the total metric score for reference stations. The percent similarity between the total scores will correspond with one of four qualitative integrity ratings ranging from severely impaired to non-impaired. If the integrity rating drops from one year to the next, degradation of water resources may be occurring somewhere upstream of the monitoring station. The emphasis is on "may," because drought years or years of excessive rainfall can confuse the interpretation. If climatic conditions can be ruled out, then a detailed look at the trends in individual components of the index may provide additional clues to the cause of the rating drop. To explicitly determine the cause(s) of water-quality impacts, more intensive studies will need to be developed. On the other hand, if the integrity rating improves from one year to the next, some form of BMP may have been implemented, intentionally or otherwise. In this case, determining the cause of the beneficial impact is important in determining that it sustains itself in the long term.

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BUDGET AND FTEs

FUNDED

Source	Act Type	Budget	FTEs

UNFUNDED

Source	Act Type	Budget	FTEs
Year 1	RES	6,000	0.05
Year 2	RES	3,000	0.05
Year 3	RES	3,000	0.05
	Total	12,000	0.15

PROJECT STATEMENT NO. RICH-N-012.000
TITLE: **ASSESS PROPER FUNCTIONING CONDITION OF RIPARIAN AREAS**

Funding Status: Funded 0.00 Unfunded 20.00

PROBLEM STATEMENT

Natural riparian areas are some of the most diverse, dynamic, and complex biophysical habitats in the terrestrial environment (Naiman *et al.* 1993). The riparian area encompasses that part of the stream channel between low and high water marks and that portion of the terrestrial landscape from the high water mark toward the uplands where vegetation may be influenced by elevated water tables or flooding and by the ability of the soils to hold water (Naiman and Decamps 1997). Riparian zones are key systems for regulating aquatic-terrestrial linkages (Ward 1989), and they may be early indicators of environmental change (Decamps 1993).

Physically, riparian areas help to control mass movements of materials and to determine channel morphology (Naiman and Decamps 1997). Material supplied to streams comes from erosion of stream banks, a process influenced by root strength and resilience, as well as from the uplands. Stream banks largely devoid of riparian vegetation are often highly unstable and subject to mass wasting, which can widen channels by several to tens of feet annually. Major bank erosion is 30 times more prevalent on nonvegetated banks exposed to currents as on vegetated banks (Beeson and Doyle 1995).

Ecologically, riparian areas: 1) provide sources of nourishment -- allochthonous inputs to rivers and herbivory; 2) control nonpoint sources of pollution, in particular, sediment and nutrients, in agricultural watersheds and watersheds being developed; and 3) create, through variations in flood duration and frequency and concomitant changes in water-table depth and plant succession, a complex of shifting habitats at different spatio-temporal scales (Naiman and Decamps 1997).

Riparian habitats have evolved in a cycle of flood and drought, but they are systems in which there is a natural repeating cycle of events. All floodplain vegetation, including riparian vegetation, therefore, is adapted to natural flood regimes. Those species found on floodplains are present because they are better adapted to the conditions than nearby upland species.

A delicate balance exists between the flora and fauna of riparian habitats and the annual flood regime. Unusually high summer flows may scour beds of aquatic vegetation, reducing cover for young-of-the-year fish, turtles, and invertebrates. Summer destruction of these plant beds may affect waterfowl food supply and survival the following winter. Ill-timed high flows may destroy larvae of amphibians by flushing them from pools and backwaters. Ground-nesting birds in riparian habitats may also experience high mortality of nestlings.

Other than a cursory knowledge of the plant species present in the park, the riparian areas in the park units are unstudied. The maintenance of healthy riparian systems is essential in obtaining and sustaining biologically diverse Coastal Plain ecosystems. Healthy riparian systems can be described as being geologically stable with stream flow and sediment discharges that are in dynamic equilibrium with their upland watersheds, and as having wetland and riparian vegetation that has appropriate structural, age, and species diversity. When these attributes are maintained, riparian systems provide forage and cover for wildlife or domestic livestock and improve water quality by filtering sediment and recycling nutrients. If, however, any of the essential attributes are missing or degraded, or if the system becomes geologically unstable, widespread erosion may occur that will degrade water quality and cause damage or loss of wetland and riparian habitats.

The U.S. Bureau of Land Management has developed guidelines and procedures to rapidly assess whether a stream riparian area is functioning properly in terms of its hydrology, landform/soils, channel characteristics, and vegetation (Prichard *et al.* 1998). This assessment, commonly called Proper Functioning Condition, or PFC, is useful as a baseline analysis of stream condition and physical function. The basic goal of this project is to use the process for PFC to classify park riparian areas as either "proper functioning condition," "functional-at-risk," or "nonfunctional." This goal can be met by implementing a coordinated review of existing literature and tactical field investigations.

DESCRIPTION OF THE RECOMMENDED PROJECT

A riparian-wetland assessment tool called Assessing Proper Functioning Condition (Prichard *et al.* 1998) will be used to evaluate riparian systems. This technique uses an interdisciplinary team to assess riparian area "functionality" according to 17 hydrological, vegetational, and stream geomorphological (e.g. erosion, deposition, channel geometry) factors. PFC is not a quantitative field technique. An advantage of this approach is that it is less time consuming than other techniques because measurements are not required. It provides an initial screening that can separate areas that are functioning well from those in need of more intensive evaluation or management actions. In this way, money and effort can be targeted toward the higher priority issues. Originally developed by the U.S. Bureau of Land Management for assessment of riparian areas managed by that agency, the method is now being applied throughout the western U.S. by the U.S. Forest Service and the Natural Resources Conservation Service. Use of this tool on eastern U.S. riparian areas is a logical extension.

PFC is a methodology for assessing the physical functioning of a riparian-wetland area. It provides information critical to determining the health of a riparian ecosystem. PFC considers both abiotic and biotic components as they relate to the physical functioning of riparian areas, but it does not consider the biotic component as it relates to habitat requirements. For habitat analysis, other techniques must be employed.

The "functioning condition" of a riparian area refers to the stability of the physical system, which in turn is dictated by the interaction of geology, soil, water, and vegetation. A healthy or stable stream/riparian area is in dynamic equilibrium with its stream flow forces and channel processes. In a healthy system, the channel adjusts in slope and form to handle larger runoff events with limited perturbation of the channel and associated riparian-wetland plant communities.

It is important to note that evaluation of functioning condition is not simply an assessment of the ecological status or seral stage of the vegetation community. Rather, evaluation is based upon the concept that in order to manage for natural vegetation communities, the basic elements of physical habitat must first be in place and functioning properly.

Identifying streams and drainages where riparian areas are not in proper functioning condition, and those at risk of losing function, is an important first step in the ultimate goal of restoration. Physical conditions in riparian zones are excellent indicators of what is happening in a stream or in the upstream watershed area. With the results of PFC analysis, it is possible to begin to determine stream corridor and watershed restoration needs and priorities. PFC results may also be used to identify where gathering more detailed information is needed and where additional data are not needed.

Riparian Functionality Assessment

In accordance with the BLM's protocols (Prichard *et al.* 1998) for assessing riparian functionality, an interdisciplinary team with expertise in hydrology, soil science, geology, and riparian vegetation will evaluate the capability and potential of park streams in terms of riparian functionality by using existing literature and field examinations to perform the following tasks:

- identify and describe relict areas;
- review historical photos, survey notes, and other documents that indicate historical condition;
- review floral and faunal species lists;
- determine species habitat needs related to species that are/were present;
- examine soils and determine if they were saturated at one time and are now well drained;
- estimate frequency and duration of flooding on floodplains and terraces;
- identify vegetation that currently exists and determine if the same species occurred historically;
- determine the entire watershed's general condition and identify its major landforms; and
- identify limiting factors to functionality, both human-caused and natural, and determine if remedial actions are needed.

Based on the evaluation of the above factors, the team will classify park riparian areas into one of the following three categories:

Proper Functioning Condition: Stream/riparian areas are functioning properly when adequate vegetation, landform, or large woody debris is present to:

- dissipate stream energy associated with high water flows, thereby reducing erosion and improving water quality;

- filter sediment, capture bedload, and aid floodplain development;
- improve floodwater retention and ground-water recharge;
- develop root masses that stabilize stream banks against cutting action;
- develop diverse ponding and channel characteristics to provide habitat and the water depths, durations, temperature regimes, and substrates necessary for fish production, waterfowl breeding, and other uses; and
- support greater biodiversity.

Functional-at-Risk: These stream/riparian areas are in functional condition, but an existing soil, water, vegetation, or related attribute makes them susceptible to degradation. For example, a stream reach may exhibit attributes of a properly functioning system, but it may be poised to suffer severe erosion during a large storm in the future due to likely headward erosion or increased runoff associated with a recent disturbance in the watershed.

Nonfunctional: These are stream/riparian areas that clearly are not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows, and thus are not reducing erosion, improving water quality, etc., as already described. The absence of certain physical attributes, such as a floodplain where one should exist, is an indication of nonfunctioning conditions.

The product of this project will be a report containing a compendium of the standard checklist for each riparian area evaluated by the team, and summary describing the team's conclusions regarding the overall condition of the park's riparian areas. The report will also provide recommendations for restoration of any Nonfunctional riparian areas, consistent with the park's management objectives and any cultural landscape studies that include these riparian areas. Any Functional-at-Risk riparian areas will be prioritized, highest risk for degradation to lowest, and recommendations will be provided for management and or restoration of these areas also subject to the same constraints as those for Nonfunctional riparian areas.

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BUDGET AND FTEs

------------------------------FUNDED------------------------------

Source	Activity	Fund Type	Budget ($1000s)	FTEs
	Total:		0.00	0.00

----------------------------UNFUNDED-----------------------------

	Activity	Fund Type	Budget ($1000s)	FTEs
Year 1:	MON	One-time	20.00	0.05
	Total:		20.00	0.05

PROJECT STATEMENT NO. RICH-N-013.000
TITLE: BASELINE ASSESSMENT OF INSTREAM AND RIPARIAN ZONE BIOLOGICAL RESOURCES

FUNDING STATUS: FUNDED: 0.0 UNFUNDED: 30.0

PROBLEM STATEMENT

The Setting

Richmond National Battlefield Park (Richmond NBP) is 110 miles south of Washington, D.C., in east-central Virginia, and comprises 1,366 acres adjacent to the city of Richmond. The park contains 11 geographically separated units, located primarily east, northeast and southeast of the city of Richmond. Ten of the units are associated with McClellan's 1862 Peninsula Campaign and/or Grant's 1864 Overland Campaign during the Civil War. The 11th unit, which was the site of the Confederacy's Chimborazo Hospital, is the main park Visitor's Center, located within the city limits. Richmond NBP was established by Federal legislation in 1936 to "protect the Civil War battlefield resources associated with the struggle for the capital of the Confederacy and to interpret these resources so as to foster an understanding of their larger significance" (National Park Service 1996).

The units comprising Richmond NBP are situated on the peninsula formed by the James and York rivers, east of the transition zone (the Fall Line) that separates the Piedmont and Atlantic Coastal Plain Physiographic provinces. This problem statement discusses nine of the units: Beaver Dam Creek, Chickahominy Bluff, Cold Harbor (including the Garthright House), Drewry's Bluff, Fort Harrison, Gaines' Mill, Malvern Hill, and Glendale.

All of the park units are within the 64,000 mi^2 Chesapeake Bay and the 10,102 mi^2 James River watersheds. The Drewry's Bluff, Fort Harrison, Glendale, and Malvern Hill units are drained by small streams into the main stem of the James River. The Beaver Dam Creek, Chickahominy Bluff, Cold Harbor, and Gaines' Mill units are drained by small streams into the main stem of the upper Chickahominy River, which drains to the James River and ultimately to the Chesapeake Bay.

The James River watershed is the largest watershed in Virginia, drains one-fourth of the state's land area, and contains nearly one-third (1,718,945) of Virginia's population. Average flow of the 340-mile-long James River is 4,884 millions gallons per day. The James River is the third largest tributary to the Chesapeake Bay. Industries in the James River watershed include transportation, chemicals, furniture, textiles, shipping, shipbuilding, and tourism. Numerous high-density residential and commercial properties along the shores create great demand for water from the James River. A land-use map of the Coastal Plain portion of the James River watershed clearly indicates the development pressures surrounding the city of Richmond, including the three counties in which the park units are situated. The two major tributaries to the tidal portion, which extends upstream to the Fall Line in Richmond, are the Appomattox River and the Chickahominy River. The Chickahominy River watershed (470-mi^2) is characterized by suburban areas in the upper one-third and predominantly forested areas mixed with residential areas and farmland in the lower two-thirds of the watershed. Timber harvesting in the Chickahominy River watershed is an important part of the local economy.

The Problem

Current land use in the park units is approximately 70% forested and 30% open or in agricultural use. The surrounding area outside of park boundaries generally consists of open uplands in agricultural use, wooded stream corridors with swampy bottomlands, or heavily developed or industrial areas.

Many park management and resource protection issues are a result of the complex pattern of land ownership and land use within the watersheds associated with each park unit. The park owns land in Chesterfield, Hanover, Henrico and counties. Drewry's Bluff (39.5 acres) is in Chesterfield County. Beaver Dam Creek, Gaines' Mill, Cold Harbor, and the Garthright House (227 acres combined) are in Hanover County. Chickahominy Bluff, Malvern Hill/Glendale, and Fort Harrison (1,086 acres combined) are in Henrico County. The combined population of these three counties in 1990 was 490,461, with 209,274 in Chesterfield, 63,306 in Hanover, and 217,881 in Henrico (National Park Service 1996). By 2000, the combined population was 608,523, with 259,903 in Chesterfield, 86,320 in Hanover, and 262,300 in Henrico (< http://www.census.gov/main/www/ cen2000.html >). This represents a growth rate of 24% in the three counties combined, with a 24% increase in Chesterfield, 36% in Hanover, and 20% in Henrico.

There are no known studies of the aquatic and riparian flora and fauna in any of the park units. This paucity of information needs to be rectified, especially if development pressures outside of park boundaries continue. The park needs to document the current biodiversity of amphibians and reptiles, fishes, aquatic macroinvertebrates, aquatic algae and macrophytes, and riparian flora and fauna. For example, the worldwide decline in amphibian populations was initially brought to the attention of the international community in 1989. In the decade that followed, the amphibian decline issue has come to be regarded as an ecological emergency in progress. Population declines involving a large percentage of the amphibian community continue to be documented. Ranges of many species have been dramatically reduced, and species extinctions have occurred rapidly even in some protected areas. Furthermore, amphibian populations of multiple species are experiencing a surge in bizarre and perplexing abnormalities. Amphibians are considered valuable indicators of environmental quality, and concern that amphibian declines are precursors of threats to human health has invoked the attention of the public, research biologists, and policy makers.

DESCRIPTION OF RECOMMENDED PROJECT OR ACTIVITY

Objective

Provide the park with baseline data and supporting interpretations on the occurrence and distribution of instream and riparian zone biological resources of tributaries of the Chickahominy River and James River within and adjacent to the Richmond NBP units. This effort will provide park staff with important biological data upon which to base future management actions, such as: 1) identify, conserve, and where appropriate, attempt to recover all federally listed threatened and endangered species or species of special concern and their essential habitat, consistent with the Endangered Species Act; 2) identify and map the distributions of plant and animal species considered rare or unique to the park; 3) manage plant and animal populations where it is necessary to preserve and protect cultural resources and landscapes; and 4) manage exotic species to stop disruption of the accurate presentation of a cultural landscape. Upon completion, the park will be able to effectively influence future land-use decisions that affect water resources on adjacent lands or the management of adjacent lands, where appropriate.

The Project

The scope of the project is to acquire data on the occurrence, distribution, and abundance of fish, amphibians, aquatic invertebrates, aquatic plants and algae, and woody and herbaceous riparian vegetation of Chickahominy River and James River tributaries of Richmond NBP units. The following resources will be examined using noted procedures:

Sampling Reach: Establish sampling reaches at up to two sites per unit based on geomorphic channel features (Meador *et al.* 1993a), generate a planimetric reach map, and characterize channel riparian zone habitat features including depth, velocities, bed and bank substrates, type, frequency and extent of geomorphic channel units (riffles, runs, and pools), and composition, dominance and density of riparian zone vegetation.

Amphibians and Reptiles: Sample amphibians and reptiles using pitfall traps and funnels (with drift fences and bait, as necessary), visual belt transects, direct capture methods, and vocalization recording. Pitfall traps and funnels are perhaps the most widely used, often producing more species per sampling effort than direct capture. These methods require multiple visits to a sampling area, first to set up and later to check traps. Sampling should occur during the mid-to-late growing season when maximum numbers of juveniles (e.g. tadpoles) are present. However, many species are easily found only after the first few days of rain following a drought, during late-summer thunderstorms, during the first spring thaw in northern areas, during mid-day basking hours, or at night.

Fish: Document species occurrence, distribution, and abundance (Meador *et al.* 1993b) of fishes in the assessment reaches using electro fishing and seining techniques. Identify endangered, threatened, and at-risk species and associated locations, and establish sampling and identification protocols for future assessment.

Mollusks: Assess potential habitat to eliminate areas where mollusks could not occur; focus further efforts on sites where populations may still exist. Employ a variety of survey methods as appropriate, including random-area searches and timed or measured-area searches. Where mollusk populations are present and in appropriate densities, take quadrat samples or transect samples to document density. Note species present and population composition by location.

Aquatic Algae and Plants: Collect periphytic algae and vascular macrophytes (Porter *et al.* 1993) at each sampling station to document the composition, occurrence, and distribution of these groups. Subsample periphytic algae for analysis of chlorophyll and biomass as potential indicators of nutrient enrichment.

Select Water Quality/Quantity Parameters: Collect measurements of temperature, pH, dissolved oxygen, turbidity, conductivity and flow at each sampling station.

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BUDGET AND FTEs

<u>Funded</u>

Source	Act Type	Budget	FTEs

<u>Unfunded</u>

Source	Act Type	Budget	FTEs
	RES	30,000	0.1

APPENDIX B

Selected Virginia Water-Quality Standards

9 VAC 25-260-50. Numerical criteria for dissolved oxygen, pH, and maximum temperature.***

DESCRIPTION CLASS OF WATERS	DISSOLVED OXYGEN (mg/l)		pH	Maximum Temp. (°C)
	Min.	Daily Avg.		
I Open Ocean	5.0	--	6.0-9.0	--
II Estuarine Waters (Tidal Water-Coastal Zone to Fall Line)	4.0	5.0	6.0-9.0	--
III Nontidal Waters (Coastal and Piedmont Zones)	4.0	5.0	6.0-9.0	32
IV Mountainous Zones Waters	4.0	5.0	6.0-9.0	31
V Stockable Trout Waters	5.0	6.0	6.0-9.0	21
VI Natural Trout Waters	6.0	7.0	6.0-9.0	20
VII Wetlands	*	*	*	**

*This classification recognizes that the natural quality of these waters may fall outside of the ranges for D.O. and pH set forth above as water quality criteria; therefore, on a case-by-case basis, criteria for specific wetlands can be developed which reflect the natural quality of the waterbody.

**Maximum temperature will be the same as that for Classes I through VI waters as appropriate.

***The water quality criteria in 9 VAC 25-260-50 do not apply below the lowest flow averaged (arithmetic mean) over a period of seven consecutive days that can be statistically expected to occur once every 10 climatic years (a climatic year begins April 1 and ends March 31).

9 VAC 25-260-170. Fecal coliform bacteria; other waters.

A. General requirements. In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 ml at any time.

B. Disinfection policy. In waters that receive sewage discharges, all the designated uses in these waters shall be protected. The board's disinfection policy applies to these waters.

1. Sewage discharges in relation to water supply intakes. Discharges located within 15 miles upstream or one tidal cycle downstream of a water supply intake shall be disinfected in order to achieve a fecal coliform geometric mean value in the effluent equal to or less than 200 per 100 milliliters.

2. Sewage discharges into shellfish waters. When sewage discharges are permitted to or within five miles upstream of shellfish waters, they shall be disinfected in order to achieve a fecal coliform geometric mean value in the effluent equal to or less than 200 per 100 milliliters.

3. Sewage discharges into other waters. Sewage discharges into other waters shall be adequately treated and disinfected as necessary to protect all the designated uses in these waters. Generally, these discharges shall achieve a fecal coliform geometric mean value in the effluent equal to or less than 200 per 100 milliliters. However, the board, with the advice of the State Department of Health, may determine that reduced or no disinfection of a discharge is appropriate on a seasonal or year-round basis. In making such a determination, the board shall consider the designated uses of these waters and the seasonal nature of those uses. Such determinations will be made during the process of approving, issuing, or reissuing the discharge permit and shall be in conformance with a board approved site-specific use-attainability analysis performed by the permittee. When making a case-by-case determination concerning the appropriate level of disinfection for sewage discharges into these waters, the board shall provide a 45-day public notice period and opportunity for a public hearing.

9 VAC 25-260-190 General Requirements for Groundwater Standards

Except where otherwise specified, groundwater quality standards shall apply statewide and shall apply to all groundwater occurring at and below the uppermost seasonal limits of the water table. In order to prevent the entry of pollutants into groundwater occurring in any aquifer, a soil zone or alternate protective measure or device sufficient to preserve and protect present and anticipated uses of groundwater shall be maintained at all times. Zones for mixing wastes with groundwater may be allowed, upon request, but shall be determined on a case-by-case basis and shall be kept as small as possible. It is recognized that natural groundwater quality varies from area to area.

Virginia is divided into four Physiographic Provinces, namely the Coastal Plain, Piedmont and Blue Ridge, Valley and Ridge, and Cumberland Plateau. Accordingly, the Board has established certain groundwater standards specific to each individual Physiographic Province.

9 VAC 25-260-140. Criteria for surface water.

A. Instream water quality conditions shall not be acutely[2] or chronically[3] toxic except as allowed in 9 VAC 25-260-20 B (mixing zones). The following are definitions of acute and chronic toxicity conditions:

"Acute toxicity" means an adverse effect that usually occurs shortly after exposure to a pollutant. Lethality to an organism is the usual measure of acute toxicity. Where death is not easily detected, immobilization is considered equivalent to death.

"Chronic toxicity" means an adverse effect that is irreversible or progressive or occurs because the rate of injury is greater than the rate of repair during prolonged exposure to a pollutant. This includes low level, long-term effects such as reduction in growth or reproduction.

B. The following table is a list of numerical water quality criteria for specific parameters.

1. For those waters with multiple designated beneficial uses, the most stringent criteria in the following table shall apply.

2. When information has become available from the Environmental Protection Agency to calculate additional aquatic life or human health criteria not contained in the table, the board may employ these values in establishing effluent limitations or other limitations pursuant to 9 VAC 25-260-20 A necessary to protect designated uses until the board has completed the regulatory standards adoption process.

Table of Parameters[8,10]

	AQUATIC LIFE				HUMAN HEALTH	
	FRESHWATER		SALTWATER			
	ACUTE[2]	CHRONIC[3]	ACUTE[2]	CHRONIC[3]	PUBLIC WATER SUPPLIES[4]	ALL OTHER SURFACE WATERS[5]
SUBSTANCE[4]	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Acenaphthene					1,200	2,700
Aldrin [c]	3.0	0.3	1.3	0.13	0.0013	0.0014
Ammonia	See Table 1	See Table 2	See Tables 3 and 4			
Anthracene					9,600	110,000
Antimony					14	4,300
Arsenic					50	
Arsenic III[1]	360	190	69	36		
Barium					2,000	
Benzene [c]					12	710
Benzo(a) anthracene [c]					0.044	0.49
Benzo(b) fluoranthene [c]					0.044	0.49
Benzo(k) fluoranthene [c]					0.044	0.49
Benzo(a)pyrene [c]					0.044	0.49
Bromoform [c]					44	3,600
Butyl benzyl phthalate					3,000	5,200
Cadmium[1]	3.9 (See Note 9)	1.1 (See Note 9)	43	9.3		
Carbon Tetrachloride [c]					2.5	45
Chlordane [c]	2.4	0.0043	0.09	0.0040	0.0058	0.0059
Chloride	860,000	230,000			250,000**	
Chlorine Total Residual	19	11				
Chlorine Produced Oxidant			13	7.5		
Chlorodibromomethane					690	57,000
Chloroform [c]					57	4,700
2-Chlorophenol					120	400
Chlorpyrifos	0.083	0.041	0.011	0.0056		
Chromium III[1]	1700 (See Note 9)	210 (See Note 9)				
Chromium VI[1]	16	11	1,100	50		
Chrysene [c]					0.044	0.49
Copper[1]	18 (See Note 9)	12 (See Note 9)	5.9	3.8	1,300	
Cyanide	22	5.2	1.0	1.0	700	215,000
DDD [c]					0.0083	0.0084

DDE[c]					0.0059	0.0059
DDT[c]	1.1	0.0010	0.13	0.0010	0.0059	0.0059
Demeton		0.1		0.1		
Dibenz(a,h) anthracene[c]					0.044	0.49
Dibutyl phthalate					2,700	12,000
Dichloromethane[c]					47	16,000
1,2-Dichlorobenzene					2,700	17,000
1,3-Dichlorobenzene					400	2,600
1,4-Dichlorobenzene					400	2,600
Dichlorobromomethane[c]					5.6	460
1,2-Dichloroethane[c]					3.8	990
1,1-Dichloroethylene					310	17,000
2,4 Dichlorophenol					93	790
2,4-dichlorophenoxy acetic acid (2,4-D)					71	
Dieldrin[c]	2.5	0.0019	0.71	0.0019	0.0014	0.0014
Diethyl phthalate					23,000	120,000
Di-2-Ethylhexyl Phthalate[c]					18	59
2,4 Dimethylphenol					540	2,300
2,4-Dinitrotoluene[c]					1.1	91
Dioxin See 9 VAC 25-260-150						
Dissolved Oxygen See 9 VAC 25-260-50						
Endosulfan	0.22	0.056	0.034	0.0087	110	240
Endrin	0.18	0.0023	0.037	0.0023	0.76	0.81
Ethylbenzene					3,100	29,000
Fecal Coliform See Part II (9 VAC 25-260-160 et seq.) of this chapter						
Fluoranthene					300	370
Fluorene					1,300	14,000
Foaming agents (measured as methylene blue active substances)					500**	
Guthion		0.01		0.01		
Heptachlor[c]	0.52	0.0038	0.053	0.0036	0.0021	0.0021
Hexachlorocyclohexane	2.0	0.080	0.16	0.01	7	25
(Lindane)						
Hydrogen Sulfide		2.0		2.0		
Indeno(1,2,3-cd)pyrene[c]					0.044	0.49
Iron					300**	
Isophorone					6,900	490,000
Kepone		zero		zero		
Lead[1]	120 (See Note 9)	14 (See Note 9)	240	9.3	15	
Malathion		0.1		0.1		
Manganese					50**	
Mercury[1,6,7]	2.4	0.012	2.1	0.025	0.052	0.053
Methoxyclor		0.03		0.03	40	
Mirex		zero		zero		
Monochlorobenzene					680	21,000
Nickel[1]	180 (See Note 9)	20 (See Note 9)	75	8.3	610	4,600
Nitrate (as N)					10,000	
Nitrobenzene					17	1,900
Parathion	0.065	0.013				
PCB-1242[c]		0.014		0.030	0.00044	0.00045
PCB-1254[c]		0.014		0.030	0.00044	0.00045
PCB-1221[c]		0.014		0.030	0.00044	0.00045
PCB-1232[c]		0.014		0.030	0.00044	0.00045
PCB-1248[c]		0.014		0.030	0.00044	0.00045
PCB-1260[c]		0.014		0.030	0.00044	0.00045
PCB-1016[c]		0.014		0.030	0.00044	0.00045
Pentachlorophenol[c]	$e^{(1.005(pH) -4.830)}$	$e^{(1.005(pH) -5.290)}$	13	7.9	2.8	82
pH See 9 VAC 25-260-50						
Phenol					21,000	4,600,000
Phosphorus (Elemental)				0.10		
Pyrene					960	11,000
Radionuclides						
Gross Alpha Particle Activity					15 pCi/l	15 pCi/l
Beta Particle and Photon Activity (formerly manmade radionuclides)					4 mrem	4 mrem
Strontium-90					8 pCi/l	8 pCi/l
Tritium					20,000pCi/l	20,000pCi/l
Selenium[1]	20	5.0	300	71	170	11,000
Silver[1]	4.1 (See Note 9)		2.3			
Sulfate					250,000**	

Temperature See 9 VAC 25-260-50						
Tetrachloroethylene					320	3,500
Toluene					6,800	200,000
Total dissolved solids					500,000**	
Toxaphene[6] [c]	0.73	0.0002	0.21	0.0002	0.0073	0.0075
1,2,4 Trichlorobenzene					260	950
Trichloroethylene [c]					27	810
2,4,6-Trichlorophenol [c]					21	65
2-(2,4,5-Trichlorophenoxy) propionic acid (Silvex)					50	
Tributyltin	0.46	0.026	0.36	0.001		
Vinyl Chloride [c]					20	5,300
Zinc[1]	120 (See Note 9)	110 (See Note 9)	95	86	5,000**	

NOTES:

* = Hardness as calcium carbonate mg/l $CaCO_3$. The minimum hardness allowed for use in this equation shall not be less than 25 mg/l, as calcium carbonate, even if the actual ambient hardness is less than 25 mg/l as calcium carbonate. The maximum hardness value for use in this equation shall not exceed 400 mg/l as calcium carbonate, even if the actual ambient hardness is greater than 400 mg/l as calcium carbonate.

** = To maintain acceptable taste, odor or aesthetic quality of drinking water.

c = Known or suspected carcinogen, human health standards are for a risk level of 10^{-5}.

1 = All metals shall be measured as dissolved. All aquatic life criteria for metals apply to the biologically available form of the metal. Metals measured as dissolved shall be considered to be biologically available, or, because local receiving water characteristics may otherwise affect the biological availability of the metal, the biologically available equivalent measurement of the metal can be further defined by determining a Water

Effect Ratio (WER) and multiplying the numerical value shown in 9 VAC 25-260-140 B by the WER. Refer to 9 VAC 25-260-140 F.

2 = One hour average concentration not to be exceeded more than once every three years on the average.

3 = Four day average concentration not to be exceeded more than once every three years on the average except for ammonia. Ammonia is a 30 day average not to be exceeded more than once every three years on the average.

4 = Unless otherwise noted, these criteria have been calculated to protect human health from toxic effects through drinking water and fish consumption.

5 = Unless otherwise noted, these criteria have been calculated to protect human health from toxic effects through fish consumption.

6 = Chronic aquatic life values have been calculated to protect wildlife from harmful effects through ingestion of contaminated tissue. However, the criteria will also protect aquatic life from toxic effects.

7 = Chronic aquatic life criteria applies to methyl mercury. This criteria will protect the marketability of natural resources, e.g., fish and shellfish.

8 = See 9 VAC 25-260-310 for additional standards or effluent limits which are site-specific.

9 = Freshwater aquatic life criteria for these metals are expressed as a function of total hardness as $CaCO_3$ (mg/l), and as a function of the pollutant's water effect ratio (WER) as defined in 9 VAC 25-260-140 F. The equations are provided in the matrix below. To maintain consistency when using these equations to calculate criteria, intermediate calculations should be rounded to four significant digits and the final criterion's value should be rounded to two significant digits. Values displayed above in the table are examples and correspond to a total hardness of 100 mg/l and a water effect ratio of 1.0.

Acute criterion=WER $\exp\{m_A[\ln(\text{hardness}^*)]+b_A\}$

Chronic criterion=WER $\exp\{m_C[\ln(\text{hardness}^*)]+b_C\}$

	m_A	b_A	m_C	b_C
Cadmium	1.128	-3.828	0.7852	-3.490
Chromium (III)	0.8190	3.688	0.8190	1.561
Copper	0.9422	-1.464	0.8545	-1.465
Lead	1.273	-1.084	1.273	-3.259
Nickel	0.8460	1.312	0.8460	-0.8840
Silver	1.72	-6.52	.....	.....
Zinc	0.8473	0.8604	0.8473	0.7614

Note: The term "exp" represents the base e exponential function.

10 = The flows listed below are default design flows for calculating steady state waste load allocations unless statistically valid methods are employed which demonstrate compliance with the duration and return frequency of the water quality criteria.

Aquatic Life:

Acute criteria	1Q10
Chronic criteria	7Q10

Human Health:

Non-carcinogens	30Q5
Carcinogens	Harmonic mean (An exception to this is for the carcinogen dioxin. The applicable stream flow for dioxin is listed in 9 VAC 25-260-150 B.)

The following are defined for this section:

"1Q10" means the lowest flow averaged over a period of one day which on a statistical basis can be expected to occur once every 10 climatic years.

"7Q10" means the lowest flow averaged over a period of seven consecutive days that can be statistically expected to occur once every 10 climatic years.

"30Q5" means the lowest flow averaged over a period of 30 consecutive days that can be statistically expected to occur once every five climatic years.

"Averaged" means an arithmetic mean.

"Climatic year" means a year beginning on April 1 and ending on March 31.

TABLE 1***

Acute Ammonia Criteria for Freshwater

Total Ammonia (mg/liter)****

Temperature (°C)

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C
6.50	35	33	31	30	29	29	29
6.75	32	30	28	27	27	26	26
7.00	28	26	25	24	23	23	23
7.25	23	22	20	19.7	19.2	19.0	19
7.50	17.4	16.3	15.5	14.9	14.6	14.5	14.5
7.75	12.2	11.4	10.9	10.5	10.3	10.2	10.3
8.00	8.0	7.5	7.1	6.9	6.8	6.8	7.0
8.25	4.5	4.2	4.1	4.0	3.9	4.0	4.1
8.50	2.6	2.4	2.3	2.3	2.3	2.4	2.6
8.75	1.47	1.40	1.37	1.38	1.42	1.52	1.66
9.00	0.86	0.83	0.83	0.86	0.91	1.01	1.16

TABLE 2***

Chronic Ammonia Criteria for Freshwater

Total Ammonia (mg/liter)****

Temperature (°C)

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C
6.50	3.02	2.82	2.66	2.59	2.53	2.5	2.5
6.75	3.02	2.82	2.66	2.59	2.53	2.5	2.5
7.00	3.02	2.82	2.66	2.59	2.53	2.5	2.5
7.25	3.02	2.82	2.66	2.59	2.53	2.5	2.5
7.50	3.02	2.82	2.66	2.59	2.53	2.5	2.5
7.75	2.80	2.60	2.47	2.38	2.35	2.3	2.4
8.00	1.82	1.71	1.62	1.57	1.55	1.56	1.59
8.25	1.03	0.97	0.93	0.91	0.90	0.91	0.95
8.50	0.58	0.55	0.53	0.53	0.53	0.55	0.58
8.75	0.34	0.32	0.31	0.31	0.32	0.35	0.38
9.00	0.20	0.19	0.19	0.20	0.21	0.23	0.27

TABLE 3

Acute Ammonia Criteria for Saltwater

Total Ammonia (mg/liter)****

Temperature (°C)

Salinity = 10 g/kg

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C	35 C
7.0	270	191	131	92	62	44	29	21
7.2	175	121	83	58	40	27	19	13
7.4	110	77	52	35	25	17	12	8.3
7.6	69	48	33	23	16	11	7.7	5.6
7.8	44	31	21	15	10	7.1	5.0	3.5
8.0	27	19	13	9.4	6.4	4.6	3.1	2.3
8.2	18	12	8.5	5.8	4.2	2.9	2.1	1.5
8.4	11	7.9	5.4	3.7	2.7	1.9	1.4	1.0
8.6	7.3	5.0	3.5	2.5	1.8	1.3	0.98	0.75
8.8	4.6	3.3	2.3	1.7	1.2	0.92	0.71	0.56
9.0	2.9	2.1	1.5	1.1	0.85	0.67	0.52	0.44

Acute Ammonia Criteria for Saltwater

Total Ammonia (mg/l)****

Temperature (°C)

Salinity = 20 g/kg

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C	35 C
7.0	291	200	137	96	64	44	31	21
7.2	183	125	87	60	42	29	20	14
7.4	116	79	54	37	27	18	12	8.7
7.6	73	50	35	23	17	11	7.9	5.6
7.8	46	31	23	15	11	7.5	5.2	3.5
8.0	29	20	14	9.8	6.7	4.8	3.3	2.3
8.2	19	13	8.9	6.2	4.4	3.1	2.1	1.6
8.4	12	8.1	5.6	4.0	2.9	2.0	1.5	1.1
8.6	7.5	5.2	3.7	2.7	1.9	1.4	1.0	0.77
8.8	4.8	3.3	2.5	1.7	1.3	0.94	0.73	0.56
9.0	3.1	2.3	1.6	1.2	0.87	0.69	0.54	0.44

Acute Ammonia Criteria for Saltwater

Total Ammonia (mg/l)****

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C	35 C
				Salinity = 30 g/kg				
7.0	312	208	148	102	71	48	33	23
7.2	196	135	94	64	44	31	21	15
7.4	125	85	58	40	27	19	13	9.4
7.6	79	54	37	25	21	12	8.5	6.0
7.8	50	33	23	16	11	7.9	5.4	3.7
8.0	31	21	15	10	7.3	5.0	3.5	2.5
8.2	20	14	9.6	6.7	4.6	3.3	2.3	1.7
8.4	12.7	8.7	6.0	4.2	2.9	2.1	1.6	1.1
8.6	8.1	5.6	4.0	2.7	2.0	1.4	1.1	0.81
8.8	5.2	3.5	2.5	1.8	1.3	1.0	0.75	0.58
9.0	3.3	2.3	1.7	1.2	0.94	0.71	0.56	0.46

TABLE 4

Chronic Ammonia Criteria for Saltwater

Total Ammonia (mg/l)****

Temperature (°C)

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C	35 C
				Salinity = 10 g/kg				
7.0	41	29	20	14	9.4	6.6	4.4	3.1
7.2	26	18	12	8.7	5.9	4.1	2.8	2.0
7.4	17	12	7.8	5.3	3.7	2.6	1.8	1.2
7.6	10	7.2	5.0	3.4	2.4	1.7	1.2	0.84
7.8	6.6	4.7	3.1	2.2	1.5	1.1	0.75	0.53
8.0	4.1	2.9	2.0	1.4	0.97	0.69	0.47	0.34
8.2	2.7	1.8	1.3	0.87	0.62	0.44	0.31	0.23
8.4	1.7	1.2	0.81	0.56	0.41	0.29	0.21	0.16
8.6	1.1	0.75	0.53	0.37	0.27	0.20	0.15	0.11
8.8	0.69	0.50	0.34	0.25	0.18	0.14	0.11	0.08
9.0	0.44	0.31	0.23	0.17	0.13	0.10	0.08	0.07

Chronic Ammonia Criteria for Saltwater

Total Ammonia (mg/l)****

Temperature (°C)

Salinity = 20 g/kg

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C	35 C
7.0	44	30	21	14	9.7	6.6	4.7	3.1
7.2	27	19	13	9.0	6.2	4.4	3.0	2.1
7.4	18	12	8.1	5.6	4.1	2.7	1.9	1.3
7.6	11	7.5	5.3	3.4	2.5	1.7	1.2	0.84
7.8	6.9	4.7	3.4	2.3	1.6	1.1	0.78	0.53
8.0	4.4	3.0	2.1	1.5	1.0	0.72	0.50	0.34
8.2	2.8	1.9	1.3	0.94	0.66	0.47	0.31	0.24
8.4	1.8	1.2	0.84	0.59	0.44	0.30	0.22	0.16
8.6	1.1	0.78	0.56	0.41	0.28	0.20	0.15	0.12
8.8	0.72	0.50	0.37	0.26	0.19	0.14	0.11	0.08
9.0	0.47	0.34	0.24	0.18	0.13	0.10	0.08	0.07

Chronic Ammonia Criteria for Saltwater

Total Ammonia (mg/l)****

Temperature (°C)

Salinity = 30 g/kg

pH	0 C	5 C	10 C	15 C	20 C	25 C	30 C	35 C
7.0	47	31	22	15	11	7.2	5.0	3.4
7.2	29	20	14	9.7	6.6	4.7	3.1	2.2
7.4	19	13	8.7	5.9	4.1	2.9	2.0	1.4
7.6	12	8.1	5.6	3.7	3.1	1.8	1.3	0.90
7.8	7.5	5.0	3.4	2.4	1.7	1.2	0.81	0.56
8.0	4.7	3.1	2.2	1.6	1.1	0.75	0.53	0.37
8.2	3.0	2.1	1.4	1.0	0.69	0.50	0.34	0.25
8.4	1.9	1.3	0.90	0.62	0.44	0.31	0.23	0.17
8.6	1.2	0.84	0.59	0.41	0.30	0.22	0.16	0.12
8.8	0.78	0.53	0.37	0.27	0.20	0.15	0.11	0.09
9.0	0.50	0.34	0.26	0.19	0.14	0.11	0.08	0.07

*** To calculate total ammonia values at different pH's and temperature values than listed in Tables 1 and 2 use the following formulas:

Formulas Used In The Calculation of Acute Criteria Values for Ammonia In Freshwater

The one-hour average concentration of ammonia (in mg/l as un-ionized NH_3) can be calculated by using the following formulas.

0.52/FT/FPH/2 = acute criteria concentration

where; FT = final temperature

$= 10^{0.03(20-T)}$

FPH = final pH

$= 1; 8.0 < pH < 9.0$

$= (1 + 10^{7.4-pH})/1.25; 6.5 < pH < 8.0$

Conversions from un-ionized to total ammonia should be performed using the following formulas;

Total ammonia criteria = calculated un-ionized ammonia criteria divided by fraction of un-ionized ammonia

Where:

Fraction of un-ionized ammonia = $1/(10^{pKa-pH} + 1)$

pKa = 0.09018 + (2729.92/(273.2 + temperature EC)).

Formulas Used In The Calculation of Chronic Criteria Values for Ammonia In Freshwater

The 30-day average concentration of ammonia (in mg/l as un-ionized NH_3) can be calculated by using the following formulas.

0.80/FT/FPH/RATIO = chronic criteria concentration

where;

FT = final temperature

= $10^{0.03(20-T)}$

FPH = final pH

= 1; 8.0 < pH < 9.0

= $(1 + 10^{7.4-pH})/1.25$; 6.5 < pH < 8.0

RATIO = 13.5; 7.7 < pH < 9.0

= $20.25 \times (10^{7.7-pH})/(1 + 10^{7.4-pH})$; 6.5 < pH < 7.7

Conversions from un-ionized to total ammonia should be performed using the following formulas:

Total ammonia criteria = calculated un-ionized ammonia criteria divided by fraction of un-ionized ammonia

Where:

Fraction of un-ionized ammonia = $1/(10^{Ka-pH} + 1)$

Where pka = 0.09018 + (2729.92/(273.2 + temperature °C)).

**** To convert these values to mg/liter N, multiply by 0.822.

APPENDIX C

LEVEL I WATER-QUALITY INVENTORY AND MONITORING
RICHMOND NATIONAL BATTLEFIELD PARK, VIRGINIA

U.S. Geological Survey
1730 East Parham Road
Richmond, Virginia 23228

INTRODUCTION

The U.S. Geological Survey conducted a Level I Water-Quality Inventory and Monitoring (WAQIM) data-collection effort for Richmond National Battlefield Park (Richmond NBP) from August 2001 through April 2002. The primary objective of the WAQIM program was to provide the National Park Service (NPS) and Richmond NBP with at least a nominal inventory of its natural resources and to provide those data in a data-management system consistent with park management needs. Water-quality inventory data (physical, chemical, and biological) were collected from “key” water bodies within the boundaries of Richmond NBP. The key water bodies are those waters within park boundaries that are essential to the central cultural, historical or natural resources management themes of the parks or provide habitats to threatened or endangered plants and animals. Data were collected during the fall, winter, spring, and summer over a range of hydrologic conditions. Because of the drought conditions that persisted during the study period, variations in flow between seasons were less pronounced than during normal hydrologic conditions.

Established in 1936, Richmond NBP protects 1366 acres of historic ground. Between 1861 and 1865, Union armies repeatedly set out to capture Richmond, capital of the Confederacy, and end the Civil War. Three of those campaigns came within a few miles of the city. The park commemorates eleven different sites associated with those campaigns, including the battlefields at Gaines' Mill, Malvern Hill, and Cold Harbor. Richmond NBP has eleven units, of which seven units were sampled as part of the WAQIM.

Land uses adjacent to park boundaries range from forested to urbanized. Various forms of agricultural practices are in use around and within the park boundaries. Potential threats to water-quality in the park include: (1) encroaching development and (2) agricultural activities. Parameters most sensitive to these potential water-quality threats include nutrients and bacteria. The Drewrys Bluff unit has an old landfill where leachate drains into a small tributary of the James River. Data-collection sites and the parameters analyzed were selected on the basis of the spatial distribution of land-use activities inside and immediately outside of the park’s boundaries and on the nature of the potential threats to park water quality.

DESCRIPTION OF INVENTORY PROCESS

Site Descriptions

The water-quality inventory for Richmond NBP included the periodic collection of physical, chemical, and microbiological data from fifteen sites within the seven units (Table 1). Data-collection activities were conducted in August 2001, October 2001, January 2002, and April 2002.

Table 1. Station descriptions for NBP.

Station Name	Station ID	Station Type	Description	Quad	Map Scale	Latitude	Longitude	Method of Determing Lat/Long
Beaver Dam Unit								
Beaver Dam Creek at Mechanicsville, VA	02042433	stream	Stream width was typically 12 feet wide. Surrounding area is lightly wooded. Site was 2 feet downstream of footbridge at the unit's southern boundary.	Seven Pines	1:24000	37 35' 42.93"	77 21' 32.86"	GPS, Unit 3
Chickahominy Bluff Unit								
Chickahominy River Trib 12 at Boundary near Richmond, VA	0204243350	stream	Stream width was typically 3 feet wide. Surrounding area is lightly wooded. Site was 5 feet downstream of southern boundary.	Richmond	1:24000	37 35' 01"	77 23' 17"	Map
Cold Harbor Unit								
Bloody Run at Eastern boundary near Highland Springs, VA	0204243610	stream	Stream width was typically less than a foot wide. Surrounding area is wooded and has heavy underbrush. Site was 75 feet upstream of tour road and at unit's eastern boundary.	Seven Pines	1:24000	37 35' 30"	77 16' 57"	Map
Bloody Run at Western boundary near Highland Springs, VA	0204243650	stream	Stream width was typically less than 3 feet wide. Surrounding area is wooded and has heavy underbrush. Site was 25 feet downstream of foot path and at unit's western boundary.	Seven Pines	1:24000	37 35' 21.29"	77 17' 31.25"	GPS, Unit 3
Drewry's Bluff Unit								
James River trib 5 at Western Boundary at Bellwood, VA	0203853010	stream	Stream was typically 1 foot wide. Surrounding area is wooded. Site was at the western boundary.	Drewry's Bluff	1:24000	37 25' 20"	77 25' 29"	Map
James River trib 5 below Landfill at Bellwood, VA	0203853030	stream	Stream was typically 1 foot wide. Surrounding area is wooded. Site was 150 feet upstream of first leachment pipe from old landfill.	Drewry's Bluff	1:24000	37 25' 17"	77 25' 26"	Map
James River trib 5 at Eastern Boundary at Bellwood, VA	0203853050	stream	Stream was typically 1 foot wide. Surrounding area is wooded. Site was 200 feet downstream of second leachment pipe from old landfill, at the southeastern boundary.	Drewry's Bluff	1:24000	37 25' 13"	77 25' 18"	Map

Table 1. Station descriptions for NBP.

Station Name	Station ID	Datum	State	County	HUC	Elevation feet	Elevation Source	Elevation Datum
Beaver Dam Unit								
Beaver Dam Creek at Mechanicsville, VA	02042433	WGS-84	Virginia	Hanover	02080206	92	Topographic map	Gage
Chickahominy Bluff Unit								
Chickahominy River Trib 12 at Boundary near Richmond, VA	0204243350	NAD-27	Virginia	Henrico	02080206	146	Topographic map	Gage
Cold Harbor Unit								
Bloody Run at Eastern boundary near Highland Springs, VA	0204243610	NAD-27	Virginia	Hanover	02080206	170	Topographic map	Gage
Bloody Run at Western boundary near Highland Springs, VA	0204243650	WGS-84	Virginia	Hanover	02080206	135	Topographic map	Gage
Drewry's Bluff Unit								
James River trib 5 at Western Boundary at Bellwood, VA	0203853010	NAD-27	Virginia	Chesterfield	02080206	75	Topographic map	Gage
James River trib 5 below Landfill at Bellwood, VA	0203853030	NAD-27	Virginia	Chesterfield	02080206	71	Topographic map	Gage
James River trib 5 at Eastern Boundary at Bellwood, VA	0203853050	NAD-27	Virginia	Chesterfield	02080206	44	Topographic map	Gage

Table 1. Station descriptions for NBP.

Station Name	Station ID	Station Type	Description	Quad	Map Scale	Latitude	Longitude	Method of Determing Lat/Long
Fort Harrison Unit								
Coles Run trib to trib near Centralia, Va	0203854250	stream	Stream was typically 1 foot wide. Surrounding area is wooded. Site was upstream of Maintenance Way Road.	Drewry's Bluff	1:24000	37 25' 44"	77 22' 32"	Map
Coles Run trib pond near Centralia, Va	0203854210	pond	Pond was typically 15 feet wide. Surrounding area is wooded. Site was north of Battlefield Park Road.	Drewry's Bluff	1:24000	37 25' 22.48"	77 22' 37.01"	GPS, Unit 3
Gaines Mill Unit								
Boatswain Creek at Western boundary near Highland Springs, VA	0204243830	stream	Stream width was typically controled by beaver activity. Surrounding area is wooded and has heavy underbrush. Site was 75 feet west from a monument on the end of a trail at the western boundary.	Seven Pines	1:24000	37 34' 21.93"	77 17' 49.34"	GPS, Unit 3
Boatswain Creek at Eastern boundary near Highland Springs, VA	0204243790	stream	Stream width was typically less than 3 feet wide. Surrounding area is wooded and has heavy underbrush. Site was 700 feet northeast of culvert at the unit's entrance on the eastern boundary.	Seven Pines	1:24000	37 34' 38"	77 17' 21"	Map
Malvern Hill and Glendale Unit								
Crewes Channel at Route 156 near Elko, VA	0203874765	pond	Pond was typically 500 feet wide. Surrounding area is wooded, some farming on edges. Site was 5 feet upstream of Route 156.	Dutch Gap	1:24000	37 24' 31.27"	77 15' 21.41"	GPS, Unit 3
Crewes Channel at Logging Road near Elko, VA	0203874770	ponded	Pond was typically 100 feet wide. Surrounding area is wooded. Site was about a mile from Carters Mill Road on an old logging road.	Dutch Gap	1:24000	37 25' 16"	77 15' 47"	Map
Western Run at Route 156 near Elko, VA	0203874275	stream	Stream was typically 12 feet wide. Surrounding area is wooded. Site was at bridge on Route 126.	Roxbury	1:24000	37 25' 10"	77 14' 43"	Map
McDowell Creek trib NPS North Boundary near Elko, VA	0203874250	stream	Stream was typically 3 feet wide. Surrounding area is wooded. Site was about a mile from Long Bridge Road on an old logging road.	Roxbury	1:24000	37 26' 17"	77 14' 38"	Map

Table 1. Station descriptions for NBP.

Station Name	Station ID	Datum	State	County	HUC	Elevation feet	Elevation Source	Elevation Datum
Fort Harrison Unit								
Coles Run trib to trib near Centralia, Va	0203854250	NAD-27	Virginia	Henrico	02080206	105	Topographic map	Gage
Coles Run trib pond near Centralia, Va	0203854210	WGS-84	Virginia	Henrico	02080206	99	Topographic map	Gage
Gaines Mill Unit								
Boatswain Creek at Western boundary near Highland Springs, VA	0204243830	WGS-84	Virginia	Hanover	02080206	77	Topographic map	Gage
Boatswain Creek at Eastern boundary near Highland Springs, VA	0204243790	NAD-27	Virginia	Hanover	02080206	103	Topographic map	Gage
Malvern Hill and Glendale Unit								
Crewes Channel at Route 156 near Elko, VA	0203874785	WGS-84	Virginia	Henrico	02080206	44	Topographic map	Gage
Crewes Channel at Logging Road near Elko, VA	0203874770	NAD-27	Virginia	Henrico	02080206	47	Topographic map	Gage
Western Run at Route 156 near Elko, VA	0203874275	NAD-27	Virginia	Henrico	02080206	72	Topographic map	Gage
McDowell Creek trib NPS North Boundary near Elko, VA	0203874250	NAD-27	Virginia	Henrico	02080206	108	Topographic map	Gage

The Beaver Dam Creek unit (Figure 1) is a 16-acre unit located approximately six miles northeast of downtown Richmond in Hanover County on Cold Harbor Road (State Route 156) near its intersection with I-295. It contains a short section of Beaver Dam Creek, a tributary of the Chickahominy River. Beaver Dam Creek at Mechanicsville (02042433) was sampled at a site 2 feet downstream of the footbridge at the unit's southern boundary. Stream width was typically 12 feet wide. Beaver dams downstream of the sampling site contributed to ponded water with minimal flow at the sampling site. The surrounding area is lightly wooded and is surrounded by housing developments.

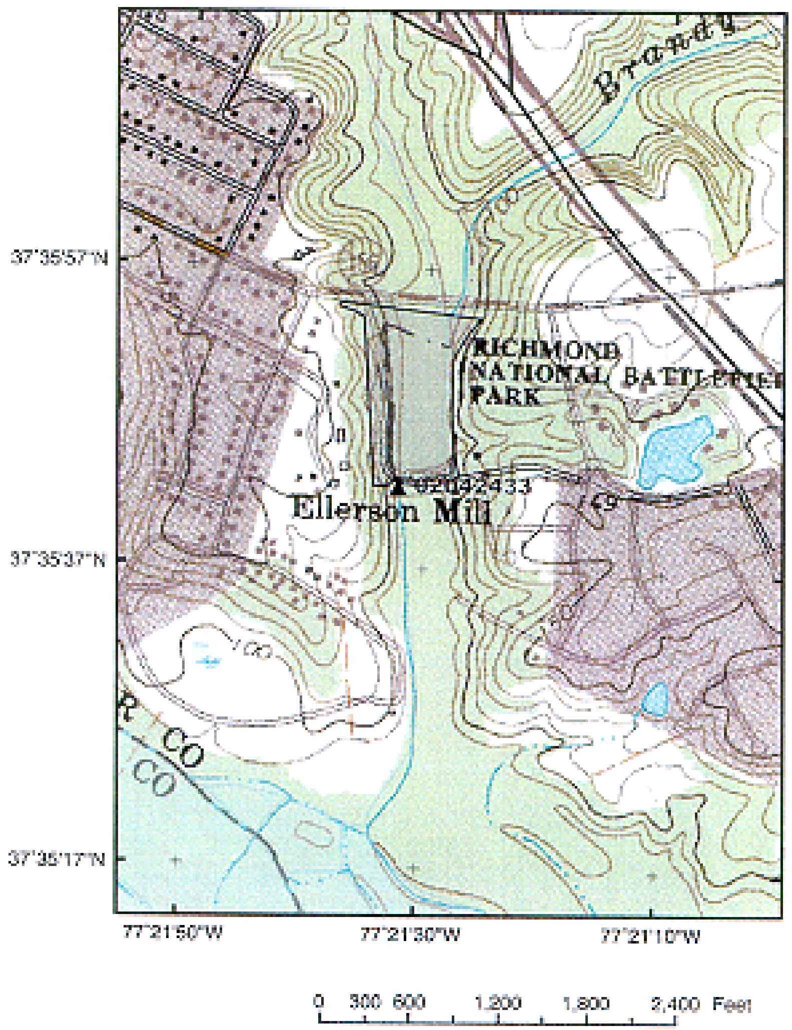

Figure 1– Beaver Dam Unit

The Chickahominy Bluff unit (Figure 2) is a 37-acre unit that lies five miles northeast of downtown Richmond on Mechanicsville Turnpike (State Route 360). The unit and a small parking area can be accessed by a short park road immediately east of Route 360. This site, Chickahominy River tributary 12 at boundary near Richmond (0204243350), was typically 3 feet wide. The site was 5 feet downstream of the southern boundary of the unit. The surrounding area is lightly wooded.

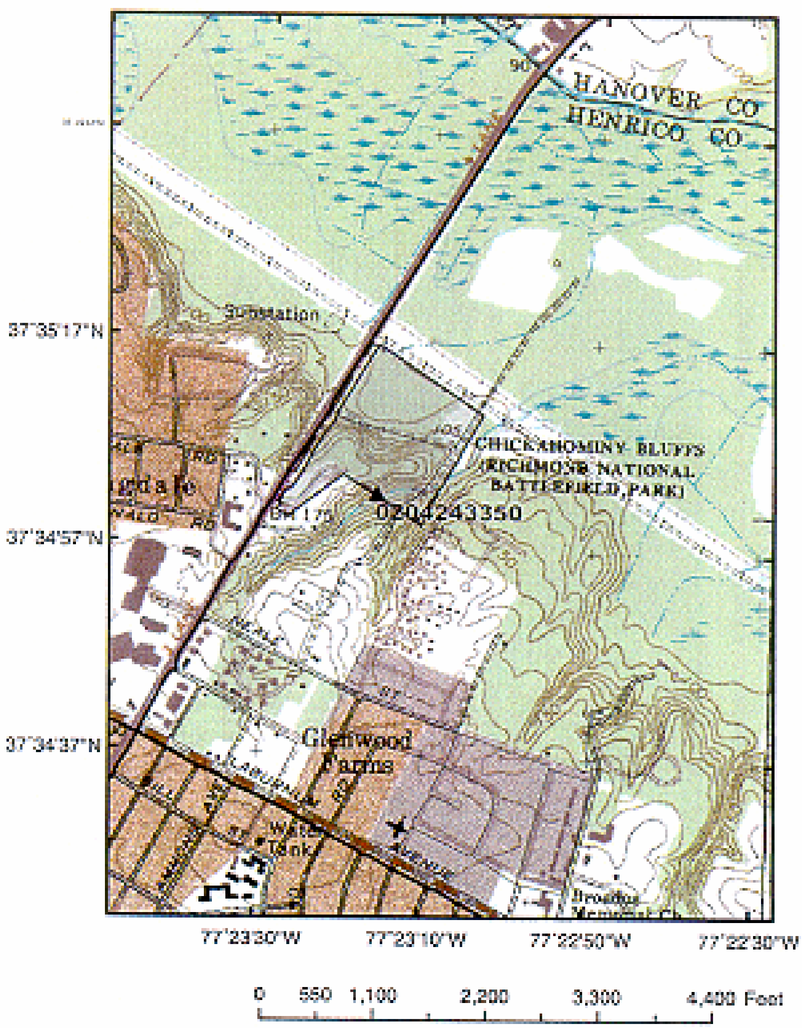

Figure 2– Chickahominy Bluffs Unit

The Cold Harbor unit (Figure 3) is a 151-acre unit on the north side of two-lane State Route 156 between the Hanover Farms subdivision and the community of Old Cold Harbor and is accessed from State Route 156 via an auto tour road. Bloody Run flows through the center of the unit. It was sampled at the eastern boundary (0204243610) and at the western boundary (0204243650) of the unit. Stream width was typically less than 3 feet wide. The surrounding area is wooded and has heavy underbrush.

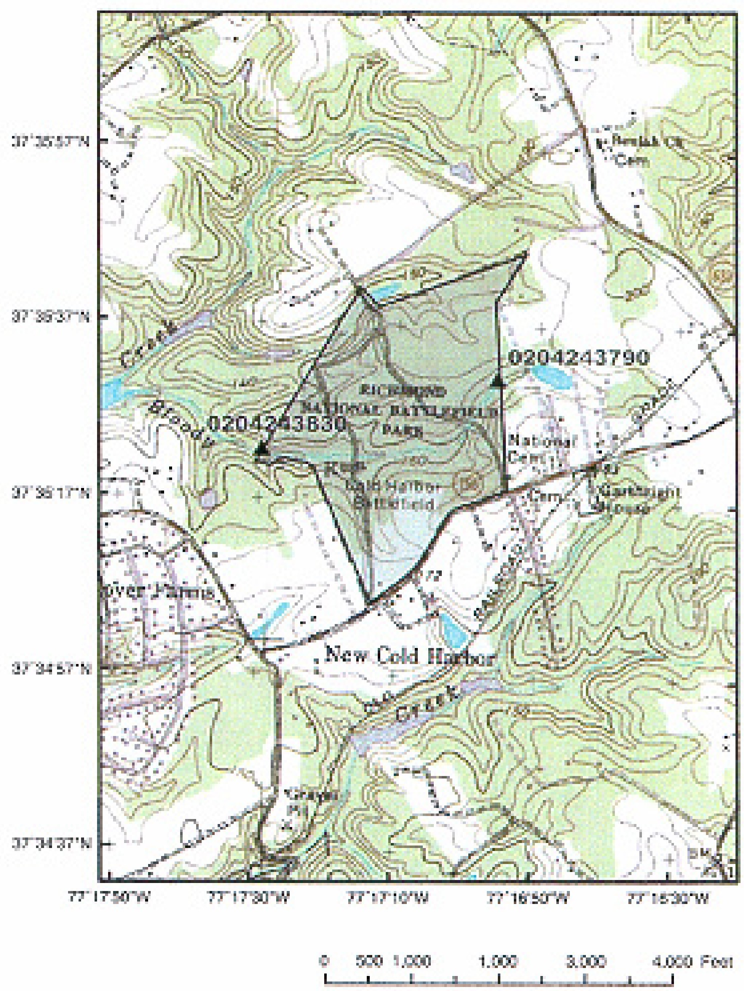

Figure 3 – Cold Harbor Unit

The Drewry’s Bluff unit (Figure 4) is a 39-acre unit approximately 8 miles south of downtown Richmond and overlooks the James River. It is accessed via Fort Darling Road off of Bellwood Road. A small tributary to the James River flows through the unit. The stream was sampled at the western boundary (0203853010), at a site 150 feet upstream of the first leachate pipe draining the landfill (0203853030), and at the eastern boundary (0203853050). The stream was typically 1 foot wide. The unit is wooded except for the landfill, which is grass covered.

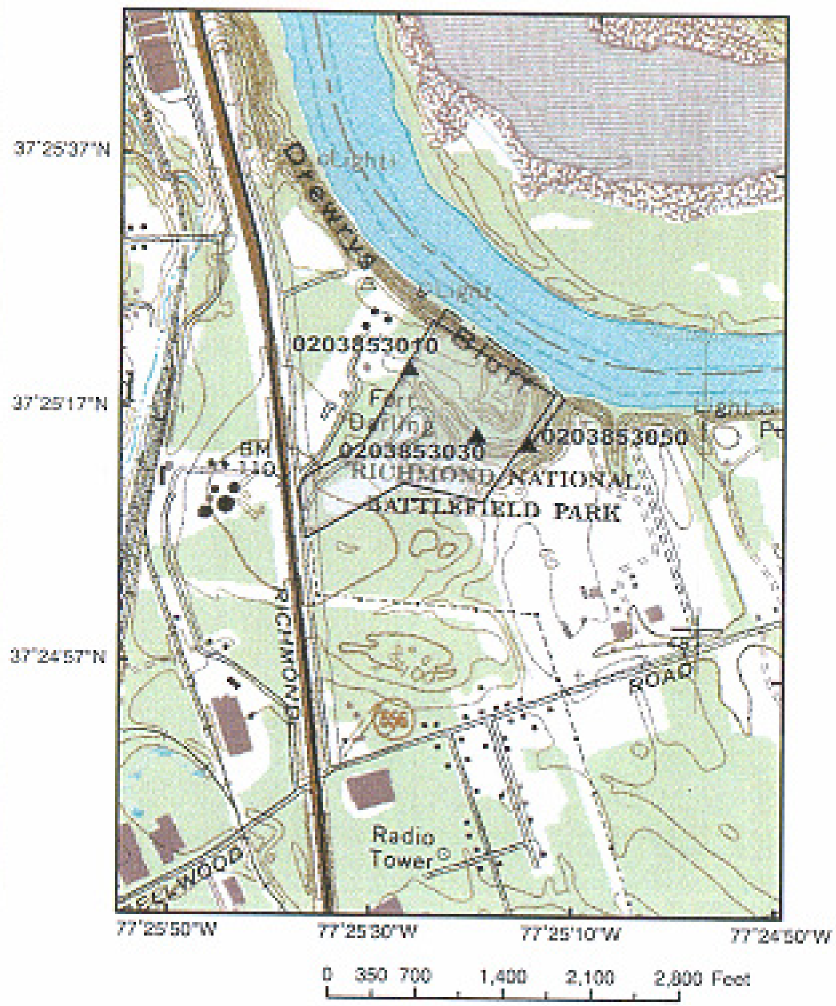

Figure 4– Drewry's Bluff Unit

The Fort Harrison unit (Figure 5) is a 313-acre unit approximately 8 miles southeast of downtown Richmond and includes a 6-mile long section of Battlefield Park Drive and Hoke Brady Road. It can be accessed via New Market (State Route 5), Mill, Varina or Kingsland Roads, or Osborne Turnpike. One site was a seasonal tributary to Coles Run just upstream of Maintenance Way (0203854250), and the second site was the ponded water along Battlefield Park Road (0203854210), which was typically 15 feet wide. The unit is wooded and has houses along Battlefield Park Drive.

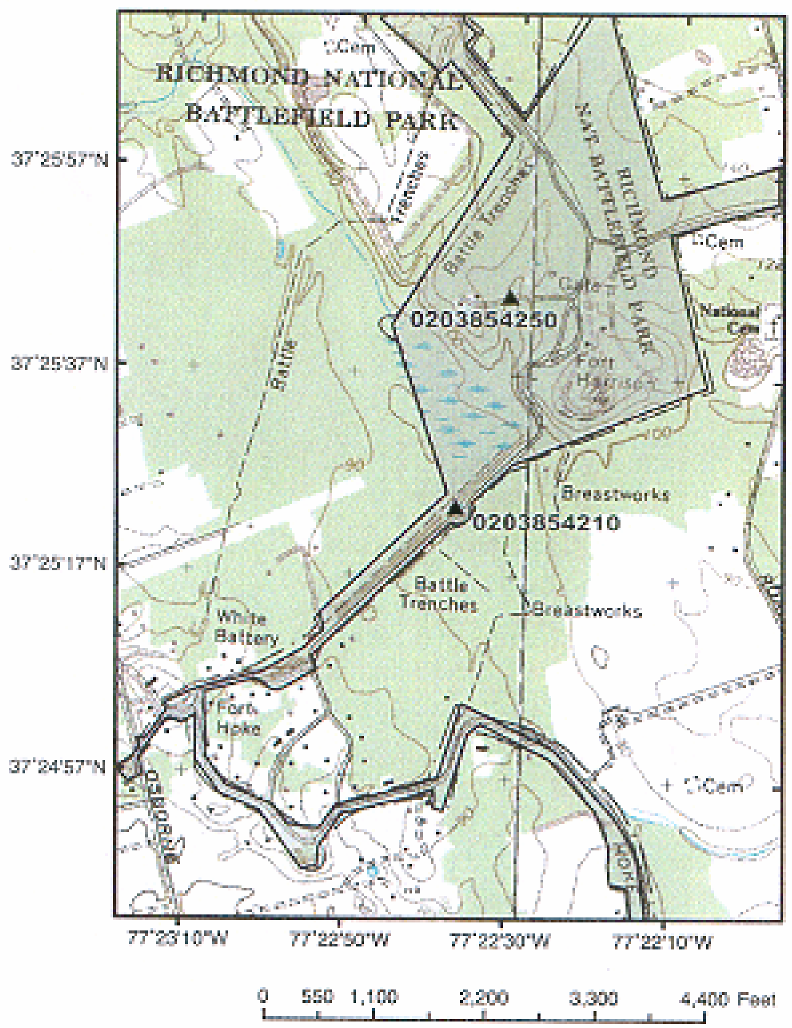

Figure 5 – Fort Harrison Unit

The Gaines' Mill unit (Figure 6) is a 60-acre unit that lies southwest of the Cold Harbor unit on the southern bank of Boatswain Creek, approximately 0.5 mile south of State Route 156 near the community of New Cold Harbor, and is accessed via Watt Farm Road. Boatswain Creek was sampled at the park's eastern boundary (0204243790) and at the western boundary (0204243830). The stream was typically 1-3 feet wide. The surrounding area is wooded and has heavy underbrush.

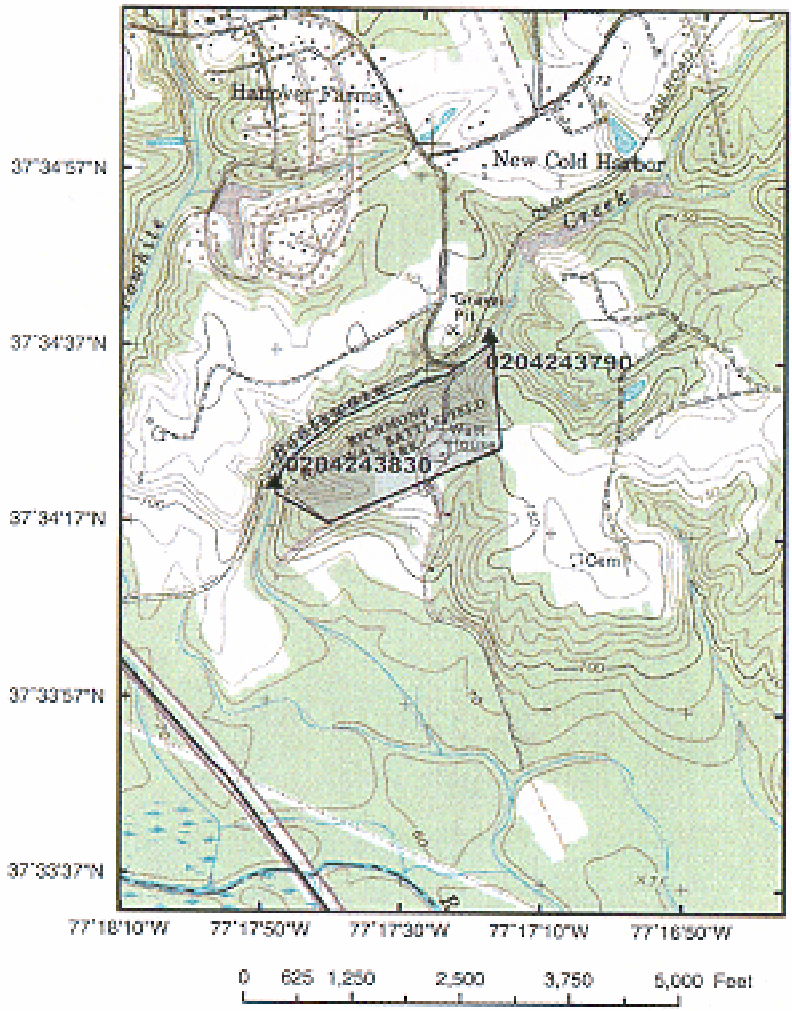

Figure 6– Gaines Mill Unit

The Malvern Hill and Glendale units (Figure 7) comprise 734 acres and are approximately 15 miles southeast of downtown Richmond on State Route 156 near its intersection with State Route 5. The units are accessible by either Carter's Mill Road or Willis Church Road. Four sites were sampled at this unit because of the unit's large area. Crewes Channel at a logging road on the northern boundary (0203874770) and at State Route 156 (0203874785) were both ponded by beaver dams. The other two sites were a tributary to McDowell Creek at the northern boundary (0203874250) of the unit and Western Run at State Route 156 bridge (0203874275). Both of these sites were flowing. The stream was typically 1-3 feet wide. The surrounding area is wooded and has heavy underbrush.

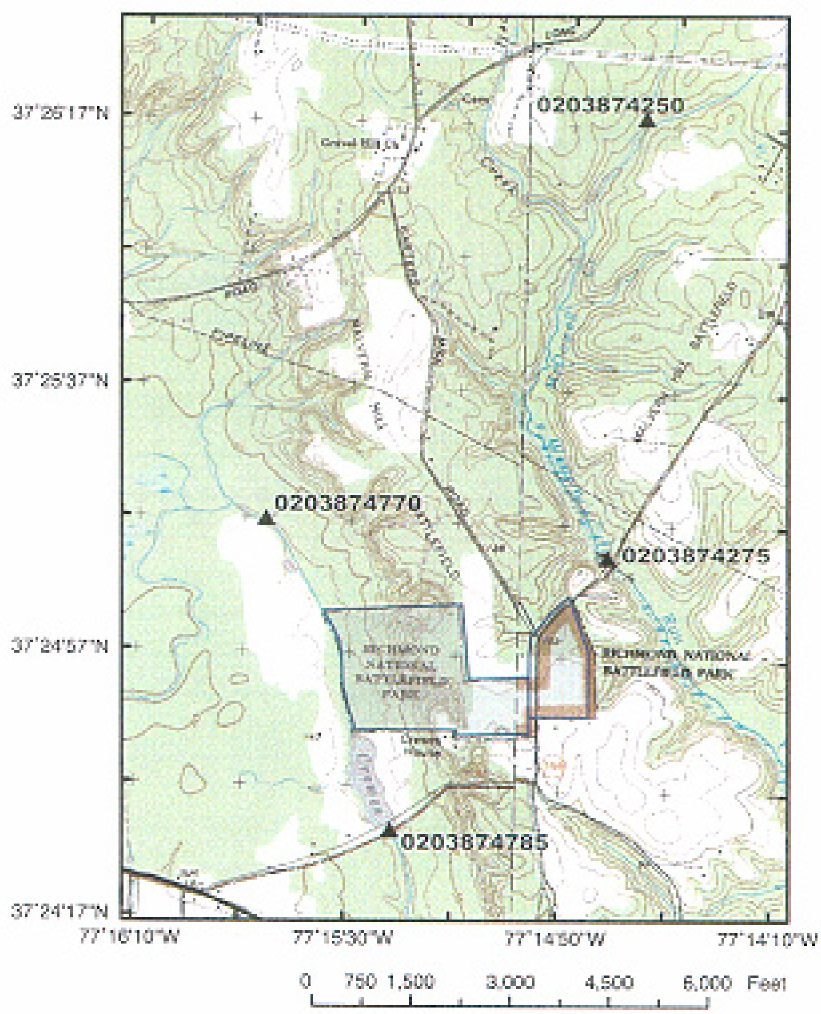

Figure 7 – Malvern Hill and Glendale Unit

Description of Data Collection

Data-collection activities were conducted in August 2001, October 2001, January 2002, and April 2002 (Table 2). Data-collection and analysis were conducted according to standard USGS protocols (U.S. Geological Survey, 1997, 1998, 1999; Rantz and others, 1982). Stream water-quality samples were collected as grab samples or cross-sectional depth-integrated samples, depending on streamflow conditions. Discharge, water temperature, pH, specific conductance, dissolved oxygen, and alkalinity were measured at every site on every visit. Water samples were collected and analyzed for nutrients and bacteria at every site on every visit. Samples collected during the October 2001 sampling trip were analyzed for major-ion and trace-element concentrations. One quality control (QC) sample was taken every sampling trip. One replicate sample and three field blanks were taken. Replicate samples are a group of samples collected in a manner such that the samples are thought to be essentially identical in composition. Field blanks can provide information on the efficacy of the equipment cleaning procedures used and on ambient atmospheric contamination.

Table 2. Data-collection schedule

Parameter	Data collection period			
	August 2001	October 2001	January 2002	April 2002
Field parameters	X	X	X	X
Fecal bacteria	X	X	X	X
Nutrients	X	X	X	X
Major Ions		X		
Trace elements		X		
Replicate		X		
Field blanks	X		X	X

PRINCIPAL INVESTIGATORS

The principal investigators of the WAQIM program were Roger M. Moberg and Karen C. Rice of the U.S. Geological Survey (USGS), Water Resources Division district office in Richmond, Virginia. Roger M. Moberg, Hydrologic Technician, implemented all fieldwork. All water-quality samples collected as part of the inventory, with the exception of bacteriological samples, were submitted for analysis to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Bacteriological samples were processed by field personnel at each site and analyzed in the Richmond, Virginia office of the USGS.

WATER-QUALITY RESULTS

Tables 3-7 provide all physical, microbiological, and chemical data collected as part of the Richmond NBP WAQIM project. Included on these tables are the four QC samples. Data generated from QC samples were used to evaluate the quality of the sampling and processing techniques as well as the data from the samples themselves. All data from the three field blanks were below lab detection limits. The data for the replicate sample did not show significant variability in constituent concentration.

Four additional files of supporting documentation are included as attachments to this report:

(1) “STATIONS.XLS”;
(2) “PARAMETER.DOC”;
(3) “WQDATA.XLS”, and
(4) “README.DOC”

“stations.xls” is a Microsoft Excel file that contains specific location information for each site where water-quality data were collected. “parameter.doc” is a Microsoft Word file that explicitly defines each water-quality parameter included in the tables of this report and also in the water-quality data spreadsheet. “ wqdata.xls” is a Microsoft Excel spreadsheet that contains all water-quality data collected during this study. “Readme.doc” is a Microsoft Word file that contains basic information related to the project, such as contact information for those who conducted the work and analyzed the samples.

Table 3. Field parameter data

[ft^3/s, cubic feet per second; mm of Hg, millimeters of mercury; °C, degrees Celsius; uS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; --, no data]

Station Number	DATE	TIME	Discharge (ft^3/s)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)	pH (units)	Specific Conductance (uS/cm)	Air Temperature (°C)	Water Temperature (°C)	Alkalinity (mg/L as $CaCO_3$)
Beaver Dam Unit										
02042433	08/20/01	1040	--	--	--	--	--	--	--	--
	08/20/01	1045	--	754	5.5	5.7	104	25.3	23.7	20
	10/16/01	1030	--	756	6.6	5.8	101	14.9	14.3	17
	01/29/02	1020	--	756	10.3	5.7	124	19.4	8	12
	04/26/02	1200	--	760	8.8	6.3	114	16.7	14.2	16
Chickahominy Bluff Unit										
0204243350	08/20/01	1210	--	754	7.4	6.2	172	26	23.4	11
	10/17/01	0930	0.01	755	9.7	6.1	153	9.6	11.3	13
	01/25/02	1050	0.11	756	10.6	5.8	124	11.5	8.9	7
	04/22/02	1500	0.64	744	8.7	6.5	117	21.7	17.2	11
Cold Harbor Unit										
0204243610	08/21/01	1200	--	756	3.3	4.8	53	27.5	20.4	10
	10/23/01	1000	--	751	0.6	5.2	73	16.7	15.2	22
	01/22/02	1410	0	761	5.3	5.6	44	10	6	5
	04/26/02	1115	0.01	760	3.5	5.6	53	17	12.6	13
0204243650	08/21/01	1100	0.19	756	5.6	4.7	67	25	19.8	3
	10/22/01	1050	0.12	755	6	4.8	70	18.4	14.9	4
	01/22/02	1020	0.13	761	10.3	5.1	64	3.9	5.4	2
	04/23/02	1130	0.59	757	7.9	5.6	61	15.3	13.6	3
Drewry's Bluff Unit										
0203853010	08/23/01	1100	--	758	7.9	5.7	142	25	21.2	19
	10/31/01	0905	--	769	0.3	5.5	124	9.8	12.6	34
	10/31/01	0915	--	769	0.3	5.5	124	9.8	12.6	34
	01/31/02	1050	--	761	2.8	6.1	589	13.1	10.9	38
	04/24/02	1000	0.04	761	10.2	9	3900	12.7	11.7	68
0203853030	08/23/01	1315	--	758	6.9	5.8	718	30.5	21.1	251
	11/01/01	1025	--	766	0.3	6	830	14.2	13.9	292
	01/31/02	1145	--	761	3.6	5.9	730	13.1	12.7	195
	04/24/02	1130	0.19	761	8.6	6.5	645	15.1	13.1	31
0203853050	08/23/01	1355	--	758	7.2	6.3	434	32	20.9	84
	11/01/01	1345	--	766	4	6	403	20.9	14.5	74
	01/31/02	1215	--	761	6.9	6.1	459	13.3	12.3	70
	04/24/02	1250	0.23	761	7.9	6.8	476	18.1	13.8	79

Table 3. Field parameter data

[ft^3/s, cubic feet per second; mm of Hg, millimeters of mercury; °C, degrees Celsius; uS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; --, no data]

Station Number	DATE	TIME	Discharge (ft^3/s)	Barometric pressure (mm of Hg)	Dissolved oxygen (mg/L)	pH (units)	Specific Conductance (uS/cm)	Air Temperature (°C)	Water Temperature (°C)	Alkalinity (mg/L as $CaCO_3$)
Fort Harrison Unit										
0203854210	08/22/01	1030	0	760	0.3	4.5	35	27.5	22.7	1
	11/02/01	1015	0	763	0.9	5	48	12.4	12.4	5
	01/24/02	1215	--	--	--	--	--	--	--	--
	01/24/02	1220	0	750	0.3	4.5	56	11.6	9.4	1
	04/22/02	1015	0	748	0.7	5.3	44	14.7	16.4	3
0203854250	04/22/02	0945	0.18	748	6.3	4.1	68	12.6	14.1	1
Gaines Mill Unit										
0204243780	08/21/01	1000	0.12	756	7.6	5.9	54	23	23	6
	10/19/01	0910	0.07	759	10.5	6	52	4	9.2	5
	01/23/02	1400	0.38	758	11.6	5.4	54	7.1	5.7	3
	04/23/02	1015	0.5	757	8.4	6.5	59	16	11.3	9
0204243830	08/21/01	0915	--	756	5.1	5.3	67	20	21.3	8
	10/18/01	1045	--	763	4	5.7	61	8.5	9.8	8
	01/23/02	1020	--	758	11.4	5.3	80	7	5.2	3
	04/23/02	0930	--	757	6.2	6.2	57	11.1	14.6	9
Malvern Hill and Glendale Unit										
0203874250	08/24/01	1300	--	755	7.3	6.6	62	27	19.2	17
	10/30/01	1015	--	764	3.8	5.3	58	12.1	9.6	15
	01/18/02	1150	0.08	755	9.3	6.1	63	11	8.8	17
	04/26/02	0945	0.14	760	7.4	6	96	16	12	12
0203874275	08/24/01	1400	--	755	6.4	6.4	56	27	23.3	14
	10/29/01	1345	--	768	7	5.8	70	9.8	10	17
	01/16/02	1045	--	761	11.6	5.5	64	5.2	3.2	12
	04/25/02	1225	--	--	--	--	--	--	--	--
	04/25/02	1230	2.2	752	8	6.4	69	20.9	14.5	12
0203874770	08/24/01	1015	--	756	2.2	5.1	52	27	22.1	11
	10/26/01	1025	0	751	7.2	5.2	74	12.9	11.8	14
	01/17/02	1400	0	755	10.5	5.7	80	11	6.2	3
	04/25/02	1015	--	752	5.1	4.9	65	17.2	13.6	2
0203874785	08/24/01	0900	--	758	5.5	5.6	94	26	25.8	27
	10/25/01	1130	--	749	8.6	5.8	101	19.3	21.1	33
	01/17/02	0935	--	755	8.6	5.8	163	10.1	5.7	33
	04/25/02	0930	--	752	3.3	6.5	149	14.4	17.5	26

Table 4. Nutrient data

[mg/L as N, milligrams per liter as nitrogen; <, less than; E, estimated value; --, no data]

Station Number	DATE	TIME	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia+ organic, dissolved (mg/L as N)	Nitrogen, ammonia+ organic, total (mg/L as N)	Nitrogen dissolved (mg/L as N)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrate+ nitrite, dissolved (mg/L as N)	Nitrogren, nitrite dissolved (mg/L as N)	Nitrogren, organic, dissolved (mg/L as N)	Nitrogren, organic, total (mg/L as N)	Nitrogren, total (mg/L as N)
Beaver Dam Unit												
02042433	08/20/01	1040	<.040	<.10	<.08	--	--	<.050	<.006	--	--	--
	08/20/01	1045	0.117	0.35	0.5	1.3	0.935	0.945	0.01	0.23	0.38	1.4
	10/16/01	1030	<.040	0.23	0.25	1.1	--	0.864	<.008	--	--	1.1
	01/29/02	1020	0.056	0.22	0.35	1.7	--	1.44	<.008	0.16	0.29	1.8
	04/26/02	1200	0.124	0.41	0.53	1	0.621	0.635	0.014	0.28	0.41	1.2
Chickahominy Bluff Unit												
0204243350	08/20/01	1210	E.033	0.11	0.18	0.89	--	0.761	<.006	--	--	0.96
	10/17/01	0930	<.040	E.06	0.1	--	--	0.562	<.008	--	--	0.67
	01/25/02	1050	0.057	0.13	0.25	0.86	--	0.735	<.008	0.07	0.19	0.98
	04/22/02	1500	0.114	0.28	0.28	0.72	--	0.445	E.006	0.16	0.17	0.73
Cold Harbor Unit												
0204243610	08/21/01	1200	0.135	0.37	0.42	1.3	--	0.905	E.003	0.24	0.29	1.3
	10/23/01	1000	E.022	0.18	0.48	0.39	0.188	0.213	0.025	--	--	0.69
	01/22/02	1410	E.028	0.13	0.31	0.53	--	0.397	<.008	--	--	0.71
	04/26/02	1115	0.105	0.35	0.56	--	--	<.050	E.005	0.24	0.45	--
0204243650	08/21/01	1100	E.021	0.19	0.27	2.6	--	2.43	<.006	--	--	2.7
	10/22/01	1050	<.040	0.11	0.15	2.6	--	2.47	<.008	--	--	2.6
	01/22/02	1020	E.026	0.16	0.16	2.7	--	2.5	<.008	--	--	2.7
	04/23/02	1130	<.040	0.21	0.48	2.3	--	2.06	<.008	--	--	2.5
Drewry's Bluff Unit												
0203853010	08/23/01	1100	<.040	0.13	0.18	3.7	3.61	3.61	0.006	--	--	3.8
	10/31/01	0905	<.040	0.15	0.48	0.67	0.345	0.523	0.178	--	--	1
	10/31/01	0915	<.040	0.15	0.41	0.68	0.347	0.526	0.179	--	--	0.94
	01/31/02	1050	0.071	0.57	0.71	0.66	--	0.092	E.004	0.5	0.64	0.8
	04/24/02	1000	0.211	0.82	1.1	1.1	0.237	0.276	0.039	0.61	0.88	1.3
0203853030	08/23/01	1315	<.040	12	10	--	--	E.026	<.006	--	--	--
	11/01/01	1025	11.1	13	12	--	--	<.050	0.042	2	0.72	--
	01/31/02	1145	7.84	8.6	8.1	--	--	<.050	0.023	0.79	0.23	--
	04/24/02	1130	0.369	0.84	0.91	0.96	0.105	0.115	0.01	0.47	0.54	1
0203853050	08/23/01	1355	3.99	4.4	4.4	4.5	0.095	0.115	0.02	0.41	0.39	4.5
	11/01/01	1345	3.87	4.4	4.4	--	--	<.050	<.008	0.56	0.53	--
	01/31/02	1215	3.36	3.4	3.7	3.6	0.154	0.18	0.026	0.03	0.33	3.9
	04/24/02	1250	2.65	3.2	3.1	3.3	0.163	0.18	0.017	0.5	0.5	3.3

Table 4. Nutrient data

[mg/L as N, milligrams per liter as nitrogen; <, less than; E, estimated value; --, no data]

Station Number	DATE	TIME	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia+ organic, dissolved (mg/L as N)	Nitrogen, ammonia+ organic, total (mg/L as N)	Nitrogen dissolved (mg/L as N)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrate+ nitrite, dissolved (mg/L as N)	Nitrogren, nitrite dissolved (mg/L as N)	Nitrogren, organic, dissolved (mg/L as N)	Nitrogren, organic, total (mg/L as N)	Nitrogren, total (mg/L as N)
Fort Harrison Unit												
0203854210	08/22/01	1030	0.407	0.94	1.9	--	--	E.028	E.004	0.53	1.4	--
	11/02/01	1015	0.643	1.2	7.4	--	--	<.050	E.005	0.54	6.8	--
	01/24/02	1215	<.040	<.10	<.10	--	--	<.050	<.008	--	--	--
	01/24/02	1220	0.353	1.3	1.4	--	--	<.050	E.005	0.99	1	--
	04/22/02	1015	0.277	1.2	1.6	--	--	E.027	0.008	0.96	1.6	--
0203854250	04/22/02	0945	<.040	0.14	0.17	--	--	<.050	<.008	--	--	--
Gaines Mill Unit												
0204243790	08/21/01	1000	0.043	0.35	0.46	--	--	E.025	<.006	0.31	0.41	--
	10/19/01	0910	<.040	0.19	0.57	0.24	--	0.049	<.008	--	--	0.62
	01/23/02	1400	E.037	0.21	0.28	0.73	--	0.513	<.008	--	--	0.79
	04/23/02	1015	0.136	0.55	0.65	0.63	--	0.08	E.004	0.42	0.51	0.73
0204243830	08/21/01	0915	0.065	0.38	0.47	1.2	--	0.782	<.006	0.32	0.41	1.3
	10/18/01	1045	0.05	0.33	0.45	--	--	E.031	<.008	0.28	0.4	--
	01/23/02	1020	0.053	0.23	0.31	0.79	--	0.559	<.008	0.18	0.26	0.87
	04/23/02	0930	0.131	0.58	0.76	0.8	--	0.225	E.005	0.45	0.63	0.99
Malvern Hill and Glendale Unit												
0203874250	08/24/01	1300	<.040	0.77	0.34	--	--	<.050	<.006	--	--	--
	10/30/01	1015	<.040	<.10	E.05	--	--	<.050	<.008	--	--	--
	01/16/02	1150	E.026	<.10	1	--	--	E.040	<.008	--	--	--
	04/26/02	0945	0.428	0.84	0.95	1.8	0.907	0.925	0.018	0.42	0.52	1.9
0203874275	08/24/01	1400	<.040	0.63	0.5	--	--	<.050	<.006	--	--	--
	10/29/01	1345	<.040	0.21	0.31	--	--	<.050	<.008	--	--	--
	01/16/02	1045	0.083	0.27	0.36	0.41	--	0.139	<.008	0.19	0.28	0.5
	04/25/02	1225	<.040	E.06	<.10	--	--	<.050	<.008	--	--	--
	04/25/02	1230	0.112	0.49	0.72	0.55	--	0.061	<.008	0.38	0.61	0.78
0203874770	08/24/01	1015	E.027	0.38	1.1	--	--	E.037	<.006	--	--	--
	10/26/01	1025	0.9	2.2	8.8	--	--	<.050	<.008	1.3	7.9	--
	01/17/02	1400	0.094	0.35	0.45	0.57	--	0.22	<.008	0.25	0.35	0.67
	04/25/02	1015	<.040	0.75	0.91	--	--	E.043	<.008	--	--	--
0203874785	08/24/01	0900	<.040	E.07	1.4	--	--	0.059	<.006	--	--	1.5
	10/25/01	1130	<.040	0.86	1.6	--	--	<.050	<.008	--	--	--
	01/17/02	0935	1.75	3.1	6.3	3.3	0.222	0.237	0.015	1.3	4.5	6.5
	04/25/02	0930	0.478	1.7	2	--	--	E.036	0.01	1.2	1.6	--

Table 4. Nutrient data--Continued

[mg/L as P, milligrams per liter as phosphorus; <, less than; E, estimated value]

Station Number	DATE	TIME	Phosphorus dissolved (mg/L as P)	Phosphorus ortho, dissolved (mg/L as P)	Phosphorus total (mg/L as P)
Beaver Dam Unit					
02042433	08/20/01	1040	<.006	<.020	<.004
	08/20/01	1045	<.006	<.020	0.05
	10/16/01	1030	E.003	<.020	0.023
	01/29/02	1020	E.004	<.020	0.025
	04/26/02	1200	0.016	E.009	0.041
Chickahominy Bluff Unit					
0204243350	08/20/01	1210	<.006	<.020	0.009
	10/17/01	0930	<.004	<.020	0.006
	01/25/02	1050	E.003	<.020	0.021
	04/22/02	1500	0.005	<.020	0.02
Cold Harbor Unit					
0204243610	08/21/01	1200	E.004	<.020	0.021
	10/23/01	1000	E.003	<.020	0.089
	01/22/02	1410	E.003	<.020	0.018
	04/26/02	1115	0.012	<.020	0.03
0204243650	08/21/01	1100	E.004	<.020	0.01
	10/22/01	1050	E.003	<.020	0.009
	01/22/02	1020	E.002	<.020	0.007
	04/23/02	1130	0.009	<.020	0.013
Drewry's Bluff Unit					
0203853010	08/23/01	1100	0.018	E.010	0.027
	10/31/01	0905	0.013	<.020	0.048
	10/31/01	0915	0.012	<.020	0.051
	01/31/02	1050	0.079	0.057	0.094
	04/24/02	1000	0.682	0.653	0.755
0203853030	08/23/01	1315	E.005	<.020	0.059
	11/01/01	1025	0.007	0.044	0.068
	01/31/02	1145	0.008	0.124	0.049
	04/24/02	1130	0.037	0.022	0.094
0203853050	08/23/01	1355	<.006	<.020	0.008
	11/01/01	1345	<.004	<.020	0.015
	01/31/02	1215	E.003	0.026	0.009
	04/24/02	1250	0.004	<.020	0.034

Table 4. Nutrient data--Continued

[mg/L as P, milligrams per liter as phosphorus; <, less than; E, estimated value]

Station Number	DATE	TIME	Phosphorus dissolved (mg/L as P)	Phosphorus ortho, dissolved (mg/L as P)	Phosphorus total (mg/L as P)
Fort Harrison Unit					
0203854210	08/22/01	1030	0.048	E.015	0.165
	11/02/01	1015	0.144	0.097	0.413
	01/24/02	1215	E.003	<.020	<.004
	01/24/02	1220	0.167	0.087	0.169
	04/22/02	1015	0.161	0.1	0.288
0203854250	04/22/02	0945	0.006	<.020	0.011
Gaines Mill Unit					
0204243790	08/21/01	1000	E.005	<.020	0.023
	10/19/01	0910	E.003	<.020	0.014
	01/23/02	1400	E.004	<.020	0.01
	04/23/02	1015	0.01	<.020	0.042
0204243830	08/21/01	0915	<.006	<.020	0.024
	10/18/01	1045	0.004	<.020	0.03
	01/23/02	1020	0.005	<.020	0.013
	04/23/02	0930	0.013	<.020	0.073
Malvern Hill and Glendale Unit					
0203874250	08/24/01	1300	0.019	<.020	0.03
	10/30/01	1015	0.005	<.020	0.013
	01/18/02	1150	E.003	E.009	0.006
	04/26/02	0945	0.027	E.012	0.055
0203874275	08/24/01	1400	0.01	<.020	0.035
	10/29/01	1345	<.004	<.020	0.023
	01/16/02	1045	0.006	<.020	0.025
	04/25/02	1225	<.004	<.020	<.004
	04/25/02	1230	0.011	<.020	0.063
0203874770	08/24/01	1015	0.008	<.020	0.107
	10/26/01	1025	0.061	<.020	0.585
	01/17/02	1400	0.01	<.020	0.025
	04/25/02	1015	0.026	<.020	0.079
0203874785	08/24/01	0900	0.006	<.020	0.209
	10/25/01	1130	0.028	<.020	0.174
	01/17/02	0935	0.046	E.015	0.454
	04/25/02	0930	0.104	0.053	0.347

Table 5. Bacteria data

[col/100 mL, colonies per 100 milliliters; --, no data; k, non-ideal colony count, <, less than; E, estimated value]

Station Number	DATE	TIME	Total coliform (col/100 mL)	Fecal coliform (col/100 mL)	Fecal streptococcus (col/100 mL)
Beaver Dam Unit					
02042433	08/20/01	1040	--	--	--
	08/20/01	1045	--	470	340
	10/16/01	1030	710	56k	38k
	01/29/02	1020	100	67	E10k
	04/26/02	1200	430	110	220
Chickahominy Bluff Unit					
0204243350	08/20/01	1210	--	310	300
	10/17/01	0930	1300	310	72k
	01/25/02	1050	420	67	1200
	04/22/02	1500	4200	680	580
Cold Harbor Unit					
0204243610	08/21/01	1200	--	E63	420
	10/23/01	1000	730	95k	110k
	01/22/02	1410	160	E10	100
	04/26/02	1115	1400	E14	E52
0204243650	08/21/01	1100	1600	570	6800
	10/22/01	1050	1400	280	590
	01/22/02	1020	350	210	140
	04/23/02	1130	1300	87	200
Drewry's Bluff Unit					
0203853010	08/23/01	1100	--	44k	1000
	10/31/01	0905	5200	28k	<10
	10/31/01	0915	5200	28k	<10
	01/31/02	1050	--	190	520k
	04/24/02	1000	E2500	950	2400
0203853030	08/23/01	1315	150k	32k	75k
	11/01/01	1025	180	<5	<5
	01/31/02	1145	650	<3	E6
	04/24/02	1130	--	330	1100
0203853050	08/23/01	1355	800	400	330k
	11/01/01	1345	180k	<10	17k
	01/31/02	1215	160	<3	E6
	04/24/02	1250	--	E58	110

Table 5. Bacteria data

[col/100 mL, colonies per 100 milliliters; --, no data; k, non-ideal colony count, <, less than; E, estimated value]

Station Number	DATE	TIME	Total coliform (col/100 mL)	Fecal coliform (col/100 mL)	Fecal streptococcus (col/100 mL)
Fort Harrison Unit					
0203854210	08/22/01	1030	120k	<10	<10
	11/02/01	1015	620	<5	<7
	01/24/02	1215	--	--	--
	01/24/02	1220	130k	50k	10k
	04/22/02	1015	--	510	73
0203854250	04/22/02	0945	1000	220	370
Gaines Mill Unit					
0204243790	08/21/01	1000	--	200	820
	10/19/01	0910	740	16k	160
	01/23/02	1400	440	E10	E38
	04/23/02	1015	1400	93	180
0204243830	08/21/01	0915		1200	2600
	10/18/01	1045	960	100	84k
	01/23/02	1020	270	29k	160
	04/23/02	0930	2600	290	330
Malvern Hill and Glendale Unit					
0203874250	08/24/01	1300	830	8k	300k
	10/30/01	1015	400	160	170
	01/18/02	1150	110	E9	40
	04/26/02	0945	500	E40	80
0203874275	08/24/01	1400	1200	410	480
	10/29/01	1345	720	340	190k
	01/16/02	1045	E63	E20	E47
	04/25/02	1225	--	--	--
	04/25/02	1230	2000	740	920
0203874770	08/24/01	1015	2400	58k	420
	10/26/01	1025	--	29k	1600
	01/17/02	1400	160	E21	83
	04/25/02	1015	--	700	320
0203874785	08/24/01	0900	140k	100k	230k
	10/25/01	1130	700	190	82k
	01/17/02	0935	170	120	110
	04/25/02	0930	560	E39	<5

Table 6. Major-element data

[mg/L, milligrams per liter; <, less than; E, estimated value; --, no data]

Station Number	DATE	TIME	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Sodium, dissolved (mg/L as Na)	Acid Neutralizing capacity (mg/L as $CaCO_3$)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
Beaver Dam Unit										
02042433	08/20/01	1040	--	--	--	--	--	--	--	--
	09/20/01	1045	--	--	--	--	--	--	--	--
	10/16/01	1030	4.15	2.8	2.75	8.5	20	13.3	E.1	4.9
	01/29/02	1020	--	--	--	--	--	--	--	--
	04/26/02	1200	--	--	--	--	--	--	--	--
Chickahominy Bluff Unit										
0204243350	08/20/01	1210	--	--	--	--	--	--	--	--
	10/17/01	0930	7.82	2.43	2.66	14.2	15	25.5	E.1	10.3
	01/25/02	1050	--	--	--	--	--	--	--	--
	04/22/02	1500	--	--	--	--	--	--	--	--
Cold Harbor Unit										
0204243610	08/21/01	1200	--	--	--	--	--	--	--	--
	10/23/01	1000	2.58	1.77	1.49	4	18	5.3	<.1	8.8
	01/22/02	1410	--	--	--	--	--	--	--	--
	04/25/02	1115	--	--	--	--	--	--	--	--
0204243650	08/21/01	1100	--	--	--	--	--	--	--	--
	10/22/01	1050	1.11	2.81	1.36	5.9	5	9.8	<.1	7.5
	01/22/02	1020	--	--	--	--	--	--	--	--
	04/23/02	1130	--	--	--	--	--	--	--	--
Drewry's Bluff Unit										
0203853010	08/23/01	1100	--	--	--	--	--	--	--	--
	10/31/01	0905	5.22	1.84	2.94	13.8	36	10.4	<.1	15.9
	10/31/01	0915	5.22	1.84	2.94	13.8	36	10.4	<.1	15.9
	01/31/02	1050	--	--	--	--	--	--	--	--
	04/24/02	1000	--	--	--	--	--	--	--	--
0203853030	08/23/01	1315	--	--	--	--	--	--	--	--
	11/01/01	1025	11.3	7.65	13.9	69.6	163	94.2	<.1	6.8
	01/31/02	1145	--	--	--	--	--	--	--	--
	04/24/02	1130	--	--	--	--	--	--	--	--
0203853050	08/23/01	1355	--	--	--	--	--	--	--	--
	11/01/01	1345	14.6	8.68	11.3	32.5	74	70.2	0.1	14.1
	01/31/02	1215	--	--	--	--	--	--	--	--
	04/24/02	1250	--	--	--	--	--	--	--	--

Table 6.Major-element data

Sulfate, dissolved (mg/L as SO_4)
--
--
3.6
--
--
--
13.1
--
--
--
0.7
--
--
--
0.5
--
--
--
5.7
5.7
--
--
--
2
--
--
--
5
--
--

Table 6. Major-element data

[mg/L, milligrams per liter; <, less than; E, estimated value; --, no data]

Station Number	DATE	TIME	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Sodium, dissolved (mg/L as Na)	Acid Neutralizing capacity (mg/L as $CaCO_3$)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
Fort Harrison Unit										
0203854210	08/22/01	1030	--	--	--	--	--	--	--	--
	11/02/01	1015	1.57	1.08	3.22	1.9	8	5.1	<.1	9
	01/24/02	1215	--	--	--	--	--	--	--	--
	01/24/02	1220	--	--	--	--	--	--	--	--
	04/22/02	1015	--	--	--	--	--	--	--	--
0203854250	04/22/02	0945	--	--	--	--	--	--	--	--
Gaines Mill Unit										
0204243790	08/21/01	1000	--	--	--	--	--	--	--	--
	10/19/01	0910	0.96	1.39	1.06	3.8	7	7.2	<.1	4.2
	01/23/02	1400	--	--	--	--	--	--	--	--
	04/23/02	1015	--	--	--	--	--	--	--	--
0204243830	08/21/01	0915	--	--	--	--	--	--	--	--
	10/18/01	1045	1.79	1.79	2.38	4.8	9	9.8	<.1	2.3
	01/23/02	1020	--	--	--	--	--	--	--	--
	04/23/02	0930	--	--	--	--	--	--	--	--
Malvern Hill and Glendale Unit										
0203874250	08/24/01	1300	--	--	--	--	--	--	--	--
	10/30/01	1015	5.58	0.567	1.23	3.6	17	7.1	<.1	13
	01/18/02	1150	--	--	--	--	--	--	--	--
	04/26/02	0945	--	--	--	--	--	--	--	--
0203874275	08/24/01	1400	--	--	--	--	--	--	--	--
	10/29/01	1345	5.7	1.25	2.97	3.9	19	8.7	<.1	7.9
	01/18/02	1045	--	--	--	--	--	--	--	--
	04/25/02	1225	--	--	--	--	--	--	--	--
	04/25/02	1230	--	--	--	--	--	--	--	--
0203874770	08/24/01	1015	--	--	--	--	--	--	--	--
	10/28/01	1025	2.51	1.2	5.75	3.6	27	9.3	<.1	1.1
	01/17/02	1400	--	--	--	--	--	--	--	--
	04/25/02	1015	--	--	--	--	--	--	--	--
0203874785	08/24/01	0900	--	--	--	--	--	--	--	--
	10/25/01	1130	10.2	2.13	1.81	4.9	28	9.7	E.1	2.4
	01/17/02	0935	--	--	--	--	--	--	--	--
	04/25/02	0930	--	--	--	--	--	--	--	--

Table 6.Major-element data

Sulfate, dissolved (mg/L as SO_4)
--
0.7
--
--
--
--
--
1.8
--
--
--
2.5
--
--
--
0.8
--
--
--
0.9
--
--
--
--
1.7
--
--
--
2.3
--
--

Table 7. Trace-element data

[ug/L, micrograms per liter; <, less than; --, no data; E, estimated value; M, presence verified, not quantified]

Station Number	DATE	TIME	Aluminum, total (ug/L as Al)	Arsenic, total (ug/L as As)	Barium, total (ug/L as Ba)	Beryllium, total (ug/L as Be)	Boron, dissolved (ug/L as B)	Cadmium, total (ug/L as Cd)	Chromium, total (ug/L as Cr)	Cobalt, total (ug/L as Co)	Copper, total (ug/L as Cu)	Iron, total (ug/L as Fe)
Beaver Dam Unit												
02042433	08/20/01	1040	--	--	--	--	--	--	--	--	--	--
	08/20/01	1045	--	--	--	--	--	--	--	--	--	--
	10/16/01	1030	50	<2	35.8	<2.50	18	<.10	<.8	<2	<1.0	1060
	01/29/02	1020	--	--	--	--	--	--	--	--	--	--
	04/28/02	1200	--	--	--	--	--	--	--	--	--	--
Chickahominy Bluff Unit												
0204243350	08/20/01	1210	--	--	--	--	--	--	--	--	--	--
	10/17/01	0930	E25	<2	38.6	<2.50	E8	E.07	<.8	<2	E.7	250
	01/25/02	1050	--	--	--	--	--	--	--	--	--	--
	04/22/02	1500	--	--	--	--	--	--	--	--	--	--
Cold Harbor Unit												
0204243610	08/21/01	1200	--	--	--	--	--	--	--	--	--	--
	10/23/01	1000	255	E1	45.2	<2.50	E7	<.10	<.8	3	E.9	11100
	01/22/02	1410	--	--	--	--	--	--	--	--	--	--
	04/26/02	1115	--	--	--	--	--	--	--	--	--	--
0204243650	08/21/01	1100	--	--	--	--	--	--	--	--	--	--
	10/22/01	1050	116	<2	56.7	<2.50	<13	<.10	<.8	2	E1.0	270
	01/22/02	1020	--	--	--	--	--	--	--	--	--	--
	04/23/02	1130	--	--	--	--	--	--	--	--	--	--
Drewry's Bluff Unit												
0203653010	08/23/01	1100	--	--	--	--	--	--	--	--	--	--
	10/31/01	0905	63	<2	62.6	<2.50	158	<.10	<.8	6	E.8	883
	10/31/01	0915	63	<2	65.6	<2.50	158	<.10	<.8	6	E.8	880
	01/31/02	1050	--	--	--	--	--	--	--	--	--	--
	04/24/02	1000	--	--	--	--	--	--	--	--	--	--
0203653030	08/23/01	1315	--	--	--	--	--	--	--	--	--	--
	11/01/01	1025	<28	11	345	<2.50	409	<.10	M	75	<1.0	78100
	01/31/02	1145	--	--	--	--	--	--	--	--	--	--
	04/24/02	1130	--	--	--	--	--	--	--	--	--	--
0203653050	08/23/01	1355	--	--	--	--	--	--	--	--	--	--
	11/01/01	1345	56	E1	175	<2.50	169	<.10	<.8	28	<1.0	4210
	01/31/02	1215	--	--	--	--	--	--	--	--	--	--
	04/24/02	1250	--	--	--	--	--	--	--	--	--	--

Table 7. Trace-element data

[ug/L, micrograms per liter; <, less than; --, no data; E, estimated value; M, presence verified, not quantified]

Station Number	DATE	TIME	Aluminum, total (ug/L as Al)	Arsenic, total (ug/L as As)	Barium, total (ug/L as Ba)	Beryllium, total (ug/L as Be)	Boron, dissolved (ug/L as B)	Cadmium, total (ug/L as Cd)	Chromium, total (ug/L as Cr)	Cobalt, total (ug/L as Co)	Copper, total (ug/L as Cu)	Iron, total (ug/L as Fe)
Fort Harrison Unit												
0203854210	08/22/01	1030	--	--	--	--	--	--	--	--	--	--
	11/02/01	1015	2010	<4	121	<2.50	25	0.25	2	3	6.1	2760
	01/24/02	1215	--	--	--	--	--	--	--	--	--	--
	01/24/02	1220	--	--	--	--	--	--	--	--	--	--
	04/22/02	1015	--	--	--	--	--	--	--	--	--	--
0203854250	04/22/02	0945	--	--	--	--	--	--	--	--	--	--
Gaines Mill Unit												
0204243790	08/21/01	1000	--	--	--	--	--	--	--	--	--	--
	10/19/01	0910	157	<2	17.5	<2.50	<13	<.10	<.8	E1	2.7	810
	01/23/02	1400	--	--	--	--	--	--	--	--	--	--
	04/23/02	1015	--	--	--	--	--	--	--	--	--	--
0204243830	08/21/01	0915	--	--	--	--	--	--	--	--	--	--
	10/18/01	1045	217	<2	24.9	<2.50	E10	<.10	<.8	E1	<1.0	1690
	01/23/02	1020	--	--	--	--	--	--	--	--	--	--
	04/23/02	0930	--	--	--	--	--	--	--	--	--	--
Malvern Hill and Glendale Unit												
0203874250	08/24/01	1300	--	--	--	--	--	--	--	--	--	--
	10/30/01	1015	48	<2	25.3	<2.50	<13	<.10	<.8	<2	<1.0	270
	01/18/02	1150	--	--	--	--	--	--	--	--	--	--
	04/26/02	0945	--	--	--	--	--	--	--	--	--	--
0203874275	08/24/01	1400	--	--	--	--	--	--	--	--	--	--
	10/29/01	1345	49	E1	30.8	<2.50	<13	E.07	<.8	<2	2.2	2550
	01/16/02	1045	--	--	--	--	--	--	--	--	--	--
	04/25/02	1225	--	--	--	--	--	--	--	--	--	--
	04/25/02	1230	--	--	--	--	--	--	--	--	--	--
0203874770	08/24/01	1015	--	--	--	--	--	--	--	--	--	--
	10/26/01	1025	1170	4	83.2	<2.50	31	E.09	M	4	3.7	4240
	01/17/02	1400	--	--	--	--	--	--	--	--	--	--
	04/25/02	1015	--	--	--	--	--	--	--	--	--	--
0203874785	08/24/01	0900	--	--	--	--	--	--	--	--	--	--
	10/25/01	1130	700	2	58.8	<2.50	14	0.21	M	<2	1.5	3020
	01/17/02	0835	--	--	--	--	--	--	--	--	--	--
	04/26/02	0930	--	--	--	--	--	--	--	--	--	--

Table 7. Trace-element data--Continued

[ug/L, micrograms per liter; <, less than; --, no data; E, estimated value; M, presence verified, not quantified]

Station Number	DATE	TIME	Lead, total (ug/L as Pb)	Lithium, total (ug/L as Li)	Manganese, total (ug/L as Mn)	Mercury, total (ug/L as Hg)	Molybdenum, total (ug/L as Mo)	Nickel, total (ug/L as Ni)	Selenium, total (ug/L as Se)	Silver, total (ug/L as Ag)
Beaver Dam Unit										
02042433	08/20/01	1040	--	--	--	--	--	--	--	--
	08/20/01	1045	--	--	--	--	--	--	--	--
	10/16/01	1030	<1	<4.4	35	<.01	<1.8	<2	<2.0	0.93
	01/29/02	1020	--	--	--	--	--	--	--	--
	04/26/02	1200	--	--	--	--	--	--	--	--
Chickahominy Bluff Unit										
0204243350	08/20/01	1210	--	--	--	--	--	--	--	--
	10/17/01	0930	<1	<4.4	18	<.01	<1.8	E2	<2.0	<.30
	01/25/02	1050	--	--	--	--	--	--	--	--
	04/22/02	1500	--	--	--	--	--	--	--	--
Cold Harbor Unit										
0204243610	08/21/01	1200	--	--	--	--	--	--	--	--
	10/23/01	1000	2	<4.4	205	E.01	<1.8	<2	<2.0	<.30
	01/22/02	1410	--	--	--	--	--	--	--	--
	04/26/02	1115	--	--	--	--	--	--	--	--
0204243650	08/21/01	1100	--	--	--	--	--	--	--	--
	10/22/01	1050	M	<4.4	29	<.01	<1.8	<2	<2.0	<.30
	01/22/02	1020	--	--	--	--	--	--	--	--
	04/23/02	1130	--	--	--	--	--	--	--	--
Drewry's Bluff Unit										
0203853010	08/23/01	1100	--	--	--	--	--	--	--	--
	10/31/01	0905	E.52	<4.4	832	E.007	<1.8	2	<2.0	<.30
	10/31/01	0915	M	<4.4	832	E.01	<1.8	2	<2.0	<.30
	01/31/02	1050	--	--	--	--	--	--	--	--
	04/24/02	1000	--	--	--	--	--	--	--	--
0203853030	08/23/01	1315	--	--	--	--	--	--	--	--
	11/01/01	1025	<1	<4.4	3750	<.01	<1.8	.8	<2.0	<.30
	01/31/02	1145	--	--	--	--	--	--	--	--
	04/24/02	1130	--	--	--	--	--	--	--	--
0203853050	08/23/01	1355	--	--	--	--	--	--	--	--
	11/01/01	1345	<1	<4.4	1590	<.01	<1.8	11	<2.0	<.30
	01/31/02	1215	--	--	--	--	--	--	--	--
	04/24/02	1250	--	--	--	--	--	--	--	--

Table 7. Trace-element data--Continued

Zinc, total (ug/L as Zn)
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E15
E15
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E22
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E18
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Table 7. Trace-element data--Continued

[ug/L, micrograms per liter; <, less than; --, no data; E, estimated value; M, presence verified, not quantified]

Station Number	DATE	TIME	Lead, total (ug/L as Pb)	Lithium, total (ug/L as Li)	Manganese, total (ug/L as Mn)	Mercury, total (ug/L as Hg)	Molybdenum, total (ug/L as Mo)	Nickel, total (ug/L as Ni)	Selenium, total (ug/L as Se)	Silver, total (ug/L as Ag)
Fort Harrison Unit										
0203854210	08/22/01	1030	--	--	--	--	--	--	--	--
	11/02/01	1015	12	<4.4	296	<.01	<1.8	8	<4.0	<.30
	01/24/02	1215	--	--	--	--	--	--	--	--
	01/24/02	1220	--	--	--	--	--	--	--	--
	04/22/02	1015	--	--	--	--	--	--	--	--
0203854250	04/22/02	0945	--	--	--	--	--	--	--	--
Gaines Mill Unit										
0204243790	08/21/01	1000	--	--	--	--	--	--	--	--
	10/19/01	0910	M	<4.4	15	<.01	<1.8	<2	<2.0	<.30
	01/23/02	1400	--	--	--	--	--	--	--	--
	04/23/02	1015	--	--	--	--	--	--	--	--
0204243830	08/21/01	0915	--	--	--	--	--	--	--	--
	10/18/01	1045	M	<4.4	56	<.01	<1.8	<2	<2.0	<.30
	01/23/02	1020	--	--	--	--	--	--	--	--
	04/23/02	0930	--	--	--	--	--	--	--	--
Malvern Hill and Glendale Unit										
0203874250	08/24/01	1300	--	--	--	--	--	--	--	--
	10/30/01	1015	<1	<4.4	32	<.01	<1.8	E1	<2.0	<.30
	01/18/02	1150	--	--	--	--	--	--	--	--
	04/26/02	0945	--	--	--	--	--	--	--	--
0203874275	08/24/01	1400	--	--	--	--	--	--	--	--
	10/29/01	1345	<1	<4.4	91	<.01	<1.8	<2	<2.0	<.30
	01/16/02	1045	--	--	--	--	--	--	--	--
	04/25/02	1225	--	--	--	--	--	--	--	--
	04/25/02	1230	--	--	--	--	--	--	--	--
0203874770	08/24/01	1015	--	--	--	--	--	--	--	--
	10/26/01	1025	8	<4.4	1500	0.02	<1.8	3	<2.0	<.30
	01/17/02	1400	--	--	--	--	--	--	--	--
	04/25/02	1015	--	--	--	--	--	--	--	--
0203874785	08/24/01	0900	--	--	--	--	--	--	--	--
	10/25/01	1130	5	<4.4	1270	<.01	<1.8	E1	<2.0	<.30
	01/17/02	0935	--	--	--	--	--	--	--	--
	04/25/02	0930	--	--	--	--	--	--	--	--

Table 7. Trace-element data--Continued

Zinc, total (ug/L as Zn)
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37
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E20
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<25
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GENERAL CLIMATIC AND HYDROLOGIC CONDITIONS

The recent hydrologic drought conditions result from precipitation patterns over the past several years. The current statewide drought began in the summer of 1997. Precipitation was well below normal during the summer and fall of 1997, allowing streamflows to decline to levels below the normal range of flows. Precipitation was well above normal during the winter of 1998, increasing groundwater storage and streamflow to levels above the normal range of flows. During the summer and fall of 1998, precipitation again was well below normal, causing a significant agricultural drought; however streamflows never declined to below normal levels until late fall because of the unusually high ground-water storage. Ground-water storage was not replenished significantly during the winter of 1999, and new record minimums were recorded during the summer of that year. Hurricanes Dennis and Floyd brought significant precipitation during the fall of 1999, which increased ground-water storage in the eastern half of the State. During the winters of 2000 and 2001, precipitation did not replenish the ground-water storage to the extent normally expected, and water levels in wells have continued to decline. Precipitation patterns during the summers of 2000 and 2001 have allowed streamflows to maintain conditions near the normal range of flow. During the study period (August 2001-April 2002), precipitation at Richmond International Airport was in deficit 10.58 inches.
One surface-water site (Chickahominy River near Providence Forge, Va 2042500) and one ground water well (372538077221501 at the Fort Harrison Unit) were used to evaluate hydrologic conditions. Analysis of streamflow records for the indicator gage (Figure 8) near the Richmond NBP study area indicates that mean daily discharges for the study period were below the median daily streamflow (based on 59 years of record) for the whole study period, except for August. The well at Fort Harrison did not show much recharge over the winter months (2001-2002) thus indicating the drought continues (Figure 9).

Figure 8. Indicator gage

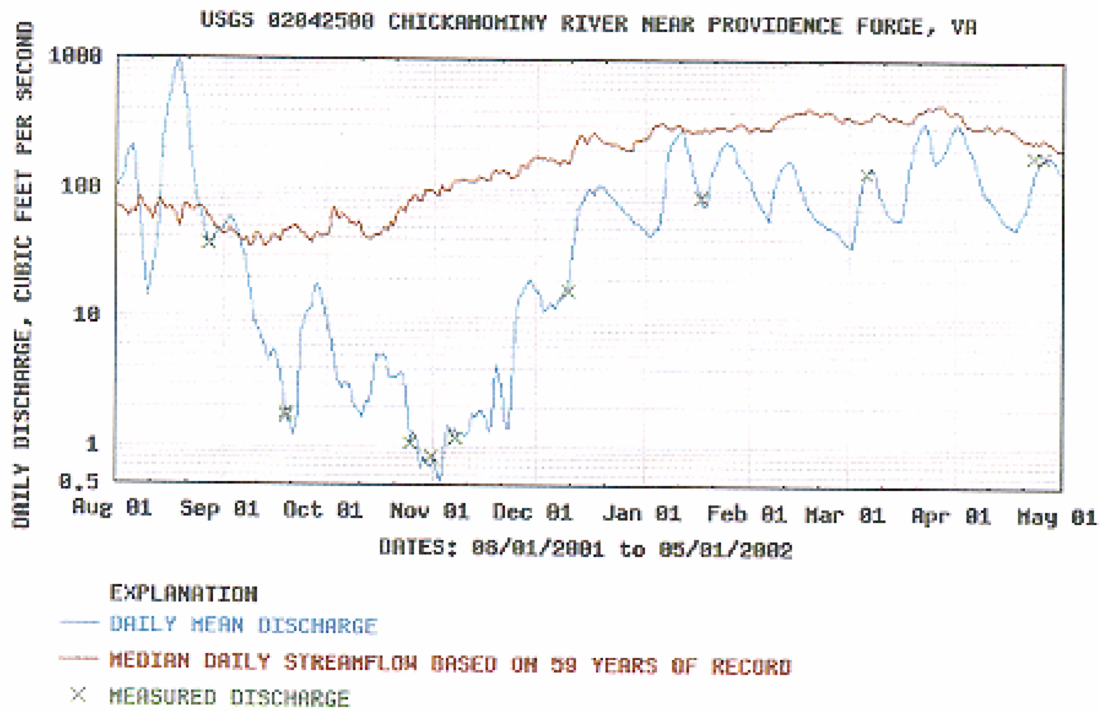
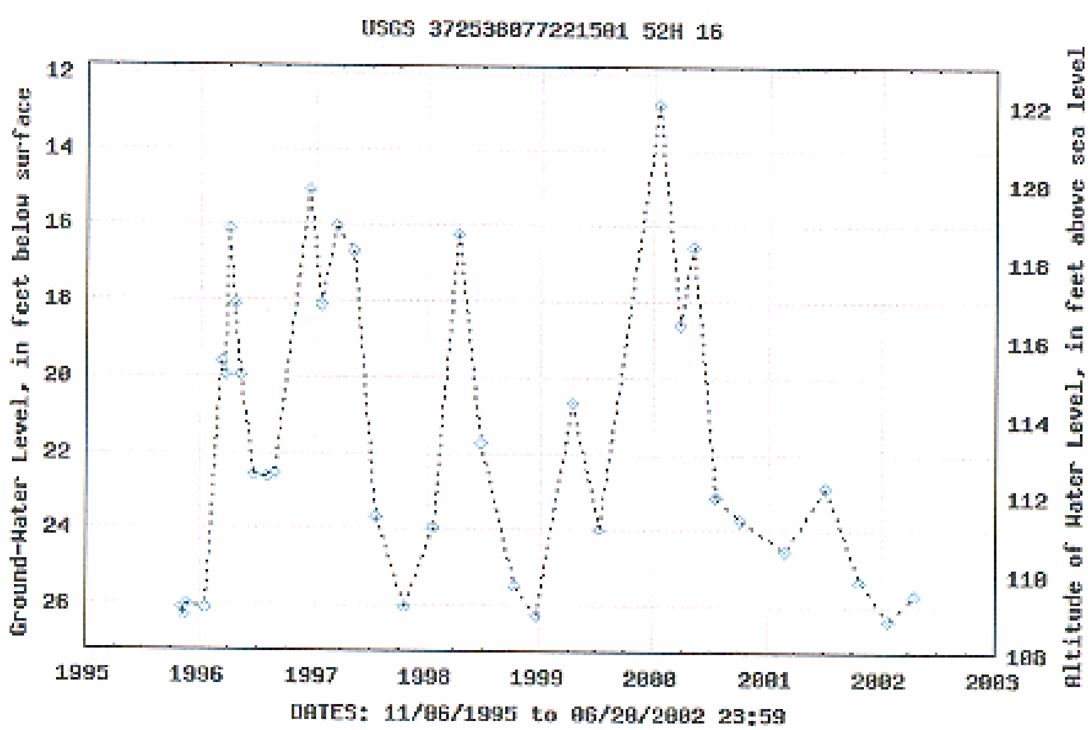


Figure 9. Well at Fort Harrison



EXCEEDENCES OF STATE WATER-QUALITY STANDARDS

In the Richmond NBP study area, all water-quality measurements were within the surface water standards established by the Virginia State Water Control Board (1997), except as noted below.

Fecal coliform: Of 58 measurements of fecal coliform bacteria made in the study area, 1 measurement exceeded the standard of 1,000 bacteria per 100 milliliters (mL). Bacteria counts of 1,200 per 100 ml were measured at station 0204243830 at the Gaines Mill unit (Boatswain Creek at western boundary near Highland Springs) on August 21, 2001.

Dissolved oxygen: There were several sites in the study with less than the minimum standard of 4.0 milligrams per liter (mg/L) for streamwater in the Piedmont zone. There were seven sites (0204243610, 0203853010, 0203853030, 0203854210, 0203874250, 0203874770, and 0203874785) with at least one incidence where the dissolved oxygen was below the standard. These sites were stagnant pools of water, with very little flow, if any.

PH: Most sites had pH values near or below the minimum standard of 6 pH units for streamwater in the Piedmont zone. These sites feed or drain swampy areas and may contain high concentrations of organic acids.

Organic ammonia: The two downstream sites at Drewrys' Bluff had elevated organic ammonia. Both sites had values that were higher than the chronic toxicity standard for freshwater, 2.13 mg/L. The two sites on Crewes Channel exceeded the chronic level for organic ammonia on one visit each.

SELECTED REFERENCES

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Virginia State Water Control Board, 1997, Surface water standards with general, statewide application: Code of Virginia, 9 VAC 25-260-5 et seq. Water Quality Standards.

White, R.K., Hayes, D.C., Guyer, J.R., and Herman, P.E., 2001, Water resources data, Virginia, water year 2001: U.S. Geological Survey Water-Data Report VA-01-1, 493p.

APPENDIX D

Attendees of Scoping Session held at Richmond National Battlefield Park, Richmond, Virginia, January 27, 2000

Name	Affiliation[1]	Phone Number	E-mail address
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Karen Rice	USGS	434-297-0106	kcrice@usgs.gov
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NPS-RNBP, National Park Service, Richmond National Battlefield Park
USGS, U.S. Geological Survey

Attendees of Scoping Session held at Richmond National Battlefield Park, Richmond, Virginia, October 24-25, 2000

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